

The 2.0L 4V TFSI Engine with AVS

Self-Study Program 922903

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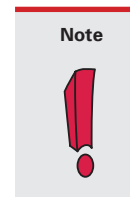
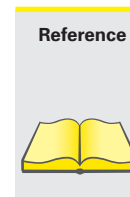
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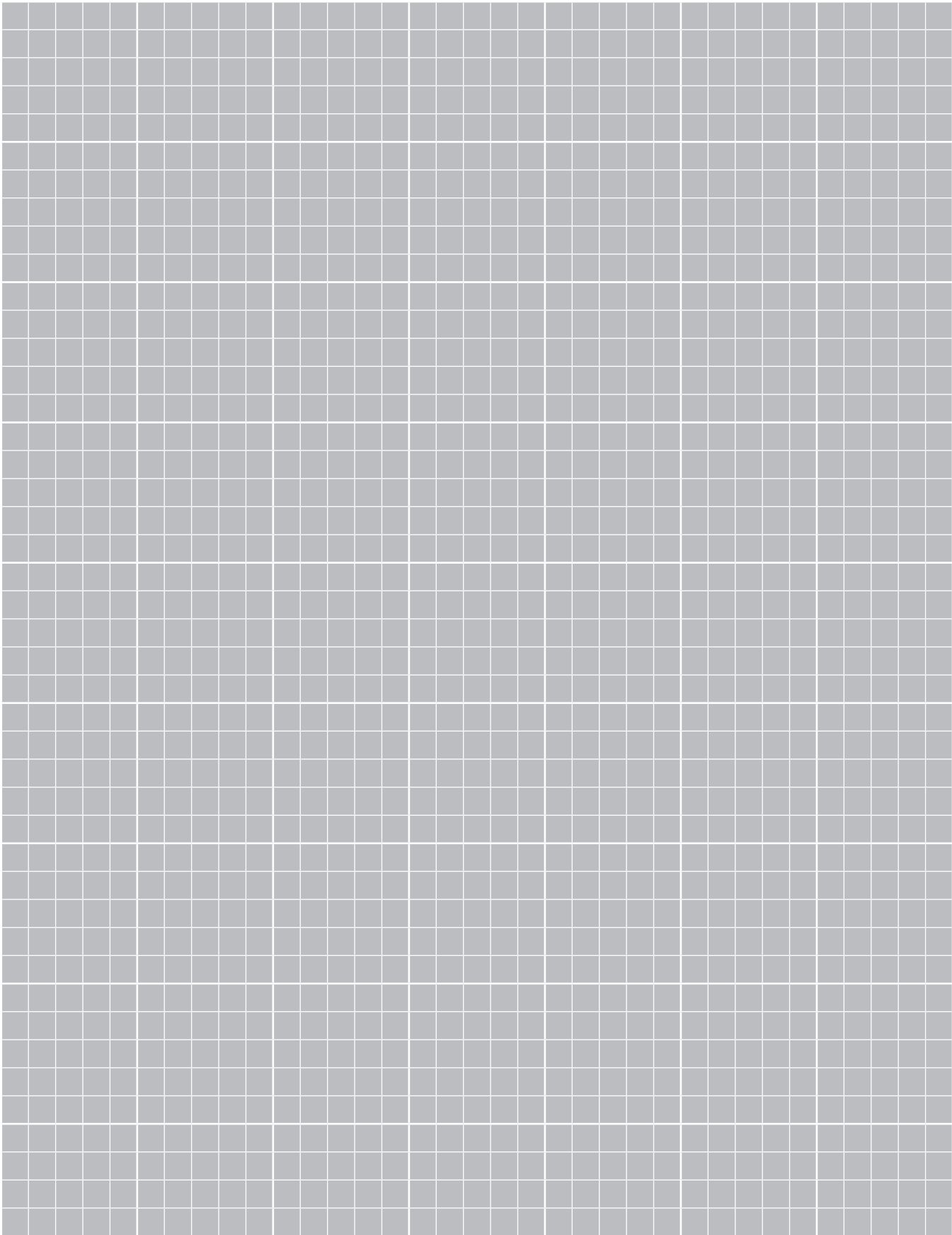
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The Self-Study Program provides introductory information regarding the design and function of new models, automotive components or technologies.

The Self-Study Program is not a Repair Manual!
All values given are intended as a guideline only and refer to the software version valid at the time of publication of the SSP.

For maintenance and repair work, always refer to the current technical literature.





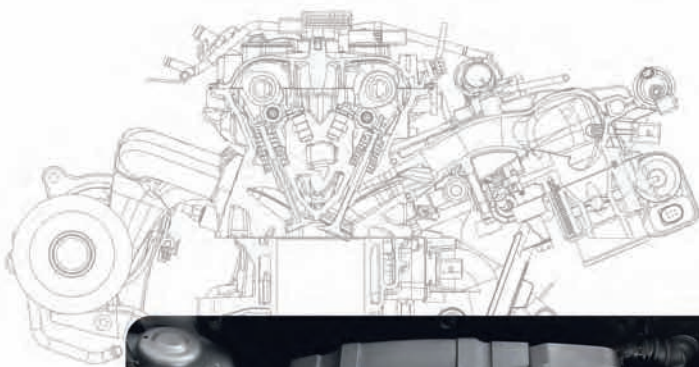
The turbocharged 2.0L 4V chain-driven AVS engine (CAEB) described in this Self-Study Program is a development of the 1.8L chain-driven engine (EA 888 family) introduced in Europe in 2006. The 1.8L engine, known as the Stage 0 engine, was the basis for the chain-driven 2.0L 4 cylinder engine (CCTA/CBFA) introduced in North America during the 2008 model year.

This EA 888 family of engines is replacing the belt-driven camshaft engines within the Volkswagen Group world wide.

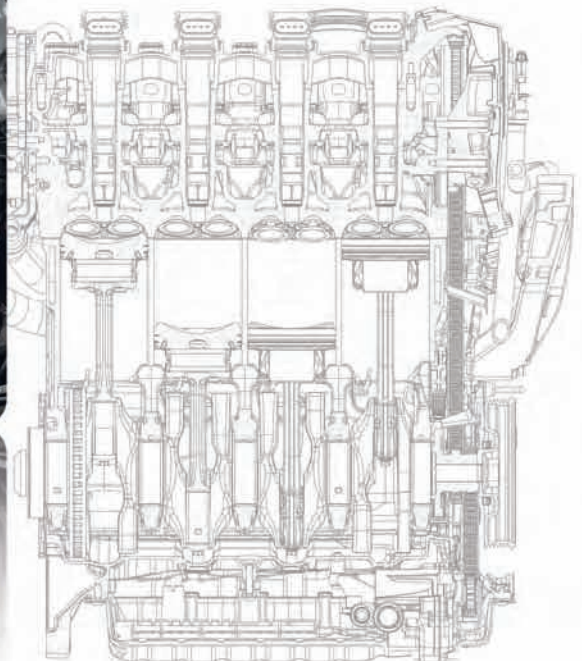
The 2.0L 4V chain-driven AVS engine is a further development of the earlier CCTA/CBFA engine. The cylinder block, crankshaft assembly and pistons of the CCTA/CBFA engine are similar to those of the CAEB engine. However, major changes to the cylinder head and the addition of the Audi Valve Lift System (AVS) to the exhaust camshaft of the CAEB distinguishes this engine from the CCTA/CBFA engines.

Also included in this Self-Study Program is a description of changes needed to make a non-AVS 2.0L 4V chain-driven engine compliant with SULEV emission standards.

To see a brief description of the development history and a specification comparison of the EA 888 engines, please see the Appendix at the end of this book.



TFSI



Introduction

Technical Description

Four Cylinder, Four Valve, FSI Turbocharged Gasoline Engine

Engine Block

- Cast Iron Crankcase
- Balancer Shafts in Crankcase
- Forged Steel Crankshaft
- Self-Regulating Sump-Mounted Oil Pump — Chain-Driven by Crankshaft
- Timing Gear Chain — Front End of Engine
- Balancer — Chain-Driven at Front End of Engine

Cylinder Head

- 4-Valve Cylinder Head
- 1 INA Intake Camshaft Adjuster
- Audi Valve Lift System (AVS) on exhaust camshaft only

Intake Manifold

- Tumble Flap

Fuel Supply

- Demand Controlled on Low and High-pressure Ends
- Multi-Port High-Pressure Injector

Engine Management

- MED 17 Engine Control
- Hot-Film Air Mass Flow with Integral Temperature Sensor
- Throttle Valve with Contactless Sensor
- Map-Controlled Ignition with Cylinder-Selective, Digital Knock Control
- Single-Spark Ignition Coils

Turbocharging

- Integral Exhaust Turbocharger
- Charge-Air Cooler
- Boost Pressure Control with Overpressure
- Electrical Wastegate Valve

Exhaust

- Single-Chamber Exhaust System with Close-Coupled Pre-Catalyst

Combustion Process

- Fuel Straight Injection



Torque/Power Curve



Specifications

Engine Code	CAEB
Type of Engine	Turbocharged Inline 4-Cylinder FSI Engine
Displacement	121 cu in (1984 cm ³)
Maximum Power	200 hp (147 kW) @ 5100 – 6000 rpm
Maximum Torque	206 lb ft (280 Nm) @ 1700 – 5000 rpm
Number of Valves Per Cylinder	4
Bore	3.2 in (82.5 mm)
Stroke	3.7 in (92.8 mm)
Compression Ratio	9.6 : 1
Firing Order	1-3-4-2
Engine Weight	317 lb (144 kg)
Engine Management	Bosch MED 17.5
Fuel Grade	95/91 RON
Exhaust Emission Standard	ULEV II / SULEV for various states

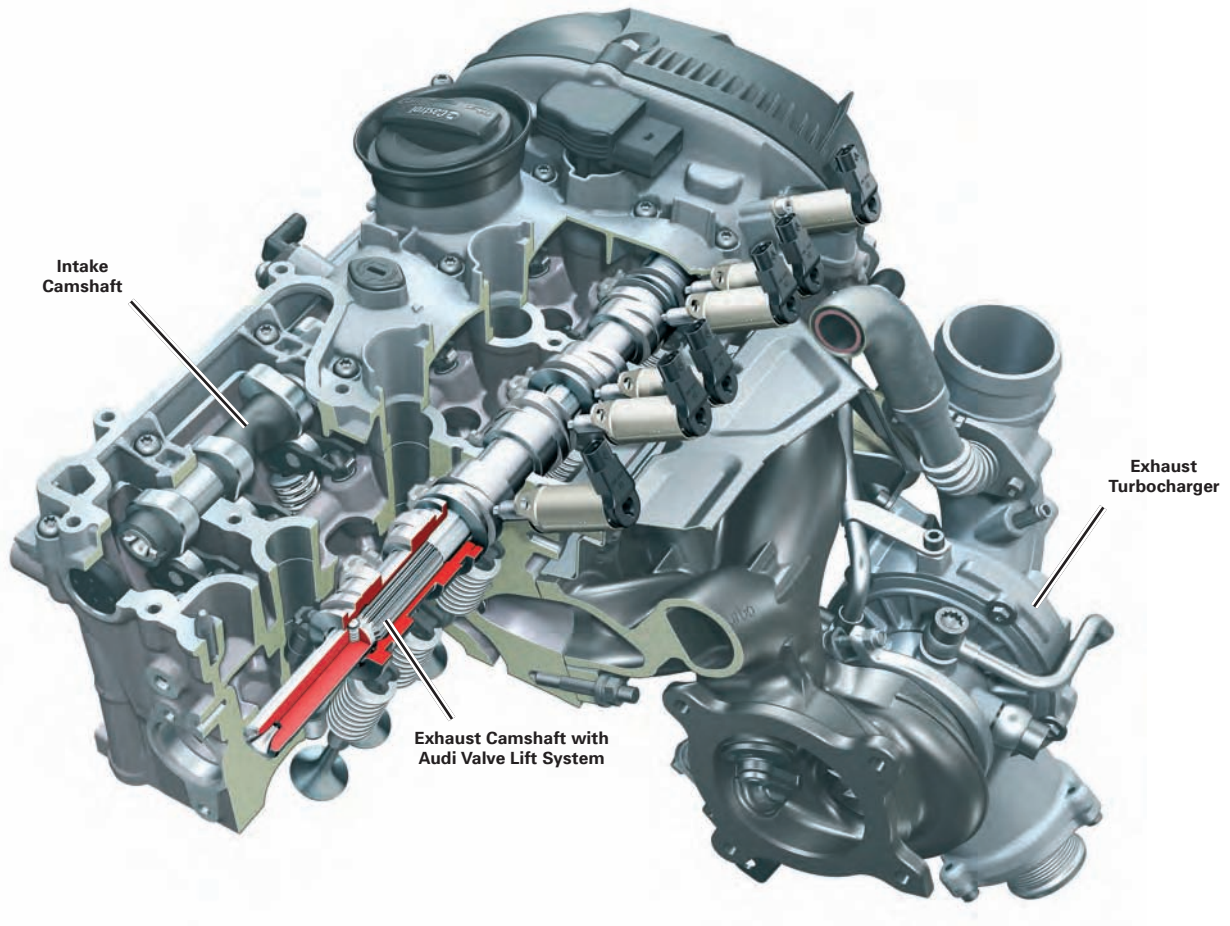
Engine Mechanicals

Audi Valve Lift System (AVS)

The Audi Valve Lift System (AVS) was developed to optimize the combustion charge cycle. AVS was introduced in the North American Region with the 3.2L V6 FSI engine in 2008.

The AVS application on the turbocharged 2.0L CAEB engine is different from that of the 3.2L V6 AVS engine. On the 2.0L CAEB engine, AVS changes the lift and timing of the exhaust valves only.

The firing order of the 2.0L CAEB engine is separated. This "firing sequence separation" means the gas pulses produced during the exhaust cycles of the individual cylinders do not effect the pulses of the previously fired cylinders. The result is referred to as "pulse charging."



The mechanical design and function of AVS on the 4-cylinder TFSI engine closely resembles the 6-cylinder naturally aspirated engine. However, different thermodynamic effects are used.

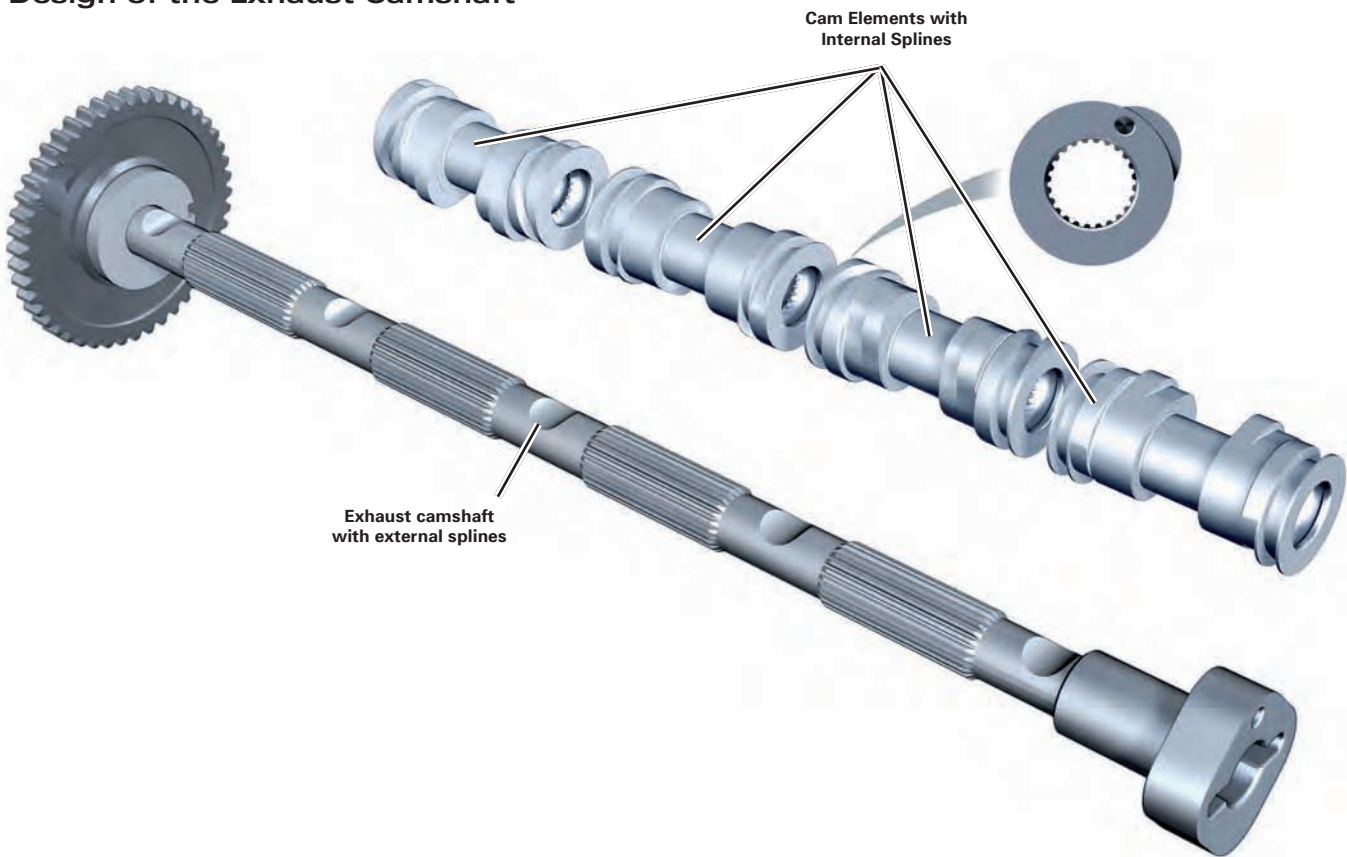
At low engine speeds, a narrow profile cam lobe contour is used. At high engine speeds the AVS changes to a wider profile cam lobe contour.

The narrow cam lobe contour provides very late exhaust valve opening. This effectively prevents back-flow of exhaust gas during the valve overlap phase due to the pre-exhaust pulse (at the exhaust valve opening point) of the cylinder, which is offset at 180° crankshaft angle. Advanced intake valve timings are therefore possible.

The positive cylinder pressure gradient allows the combustion chamber to be effectively purged. This enhances fuel mixture by reducing the residual gas content in the cylinder, and by facilitating advanced intake valve timings (because less intake air is expelled after BDC).

These improvements also result in much better response and much higher torque at low rpm. Charge pressure can be built up more quickly, making the torque curve steeper and minimizing turbo lag.

Design of the Exhaust Camshaft



Modifications to the Roller Cam Followers

The roller cam followers for the exhaust camshaft have been designed to reach both valve lift lobes on the cam elements. To achieve this, the roller is now larger in diameter and narrower in width.

At the same time, the roller cam followers have been optimized for low friction by using improved bearings. To prevent the roller cam followers from tilting downward, they are permanently connected to the support element.

For this reason, a roller cam follower can only be replaced with a complete, pre-assembled module.



Function

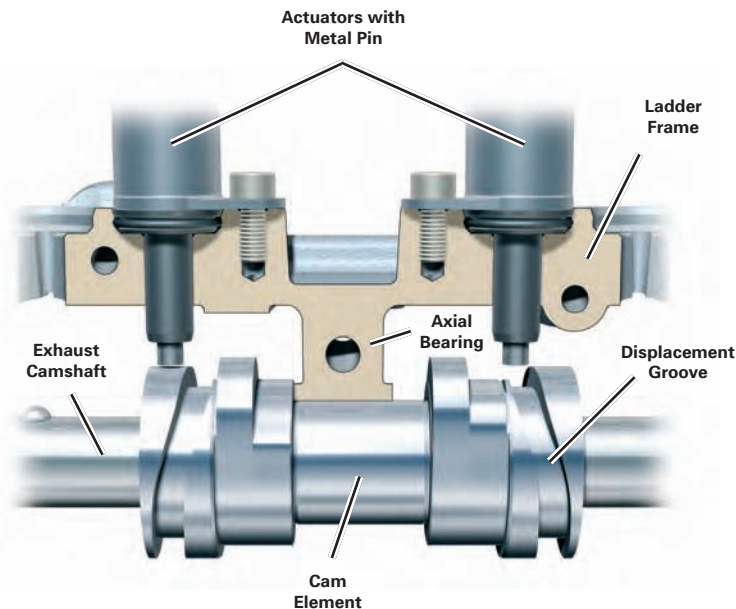
Each cylinder has its own movable cam element mounted on the exhaust camshaft. Two valve lift contours are possible for each exhaust valve. Changing-over between the large and small cam lobe contours is achieved by the longitudinal displacement of the cam elements.

The cam elements are moved on the exhaust camshaft by solenoid actuators. While one actuator switches from small valve lift to large valve lift, the other actuator switches from large valve lift to small valve lift.

The second actuator switches back from large valve lift to small valve lift. When an actuator is activated by the Engine Control Module (ECM), a metal pin is extended and engages in the displacement groove of the cam element.

The cam element is designed to move automatically when the camshaft rotates, thereby changing over both exhaust valves to the other cam lobe contour.

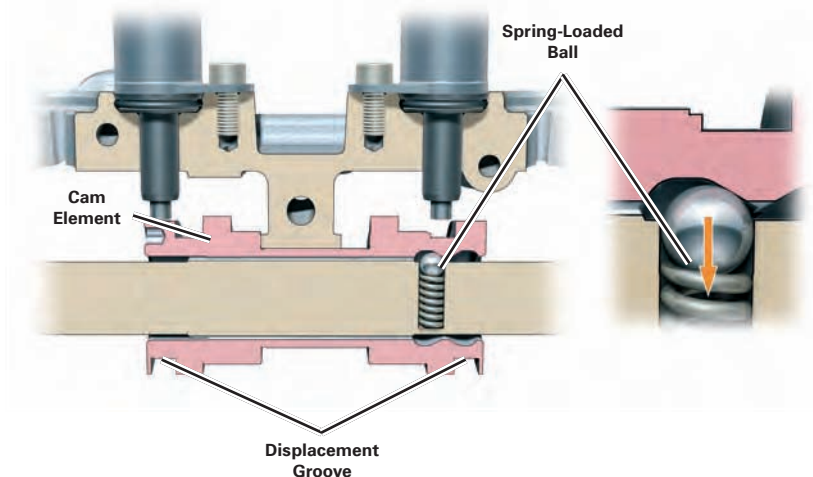
However, the displacement groove in the cam elements must be shaped so that the metal actuator pin is pushed back again after the changeover is made. The metal pin cannot be actively changed back by the ECM.



Locking of the Cam Elements

To ensure that the cam elements are not displaced too far when they are adjusted, adjustment travel is limited by a stop. The stops are camshaft bearings in the cylinder head cover.

The cam elements are located and held in place by a detent in the camshaft with spring-loaded balls.



Engine Mechanicals

Cam Lobe Contour

There are two cam lobe contours per valve on each cam element.

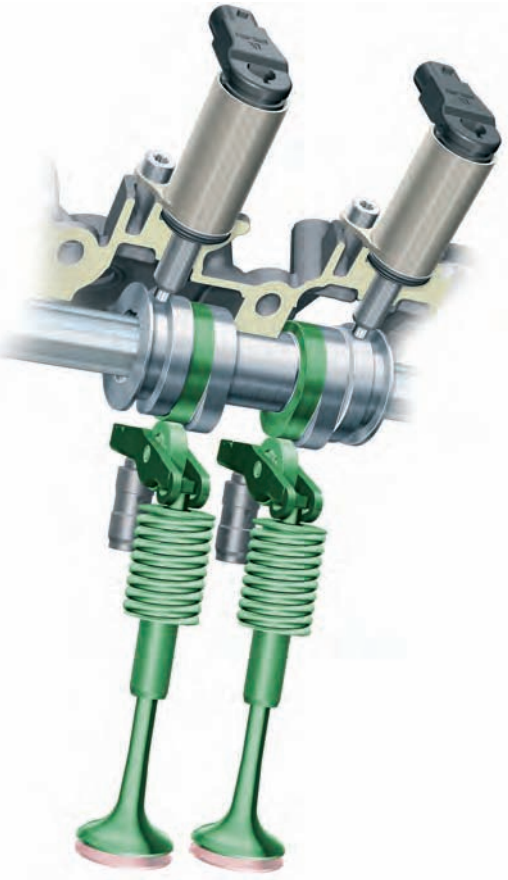
The small cam lobes (shown in green) implement a valve opening stroke of 0.25 in (6.35 mm). The length of opening is 180° crankshaft angle. The exhaust valve closes 2° after TDC.

The full stroke provided by the large cam lobes (shown in red) is 0.40 in (10 mm) with a length of opening of 215° crankshaft angle. The exhaust valve closes 8° before TDC.

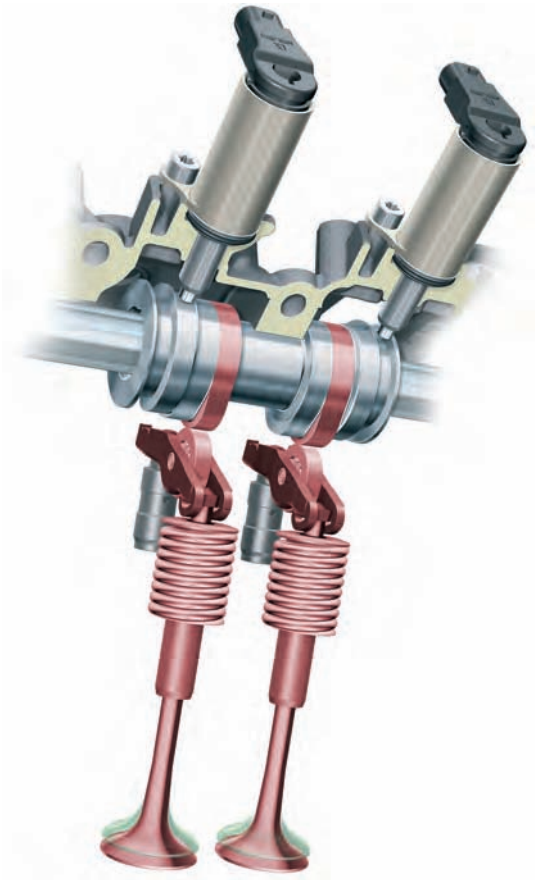


Method of Operation

Small Cam Lobes
(low engine speeds)



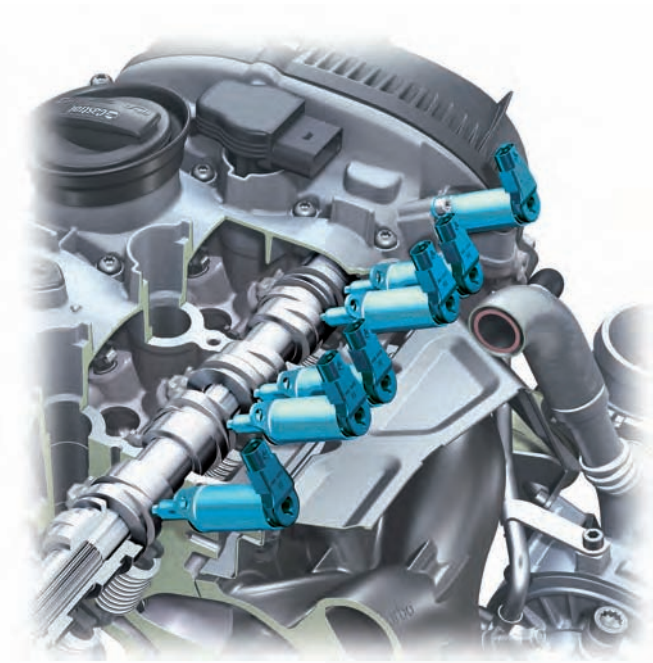
Large Cam Lobes
(high engine speeds)



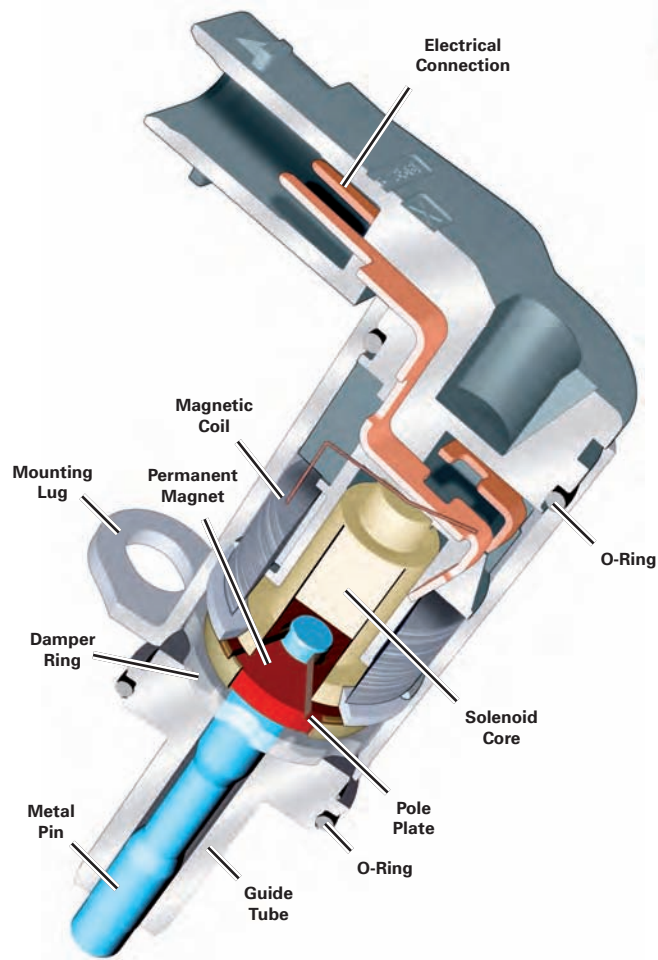
Camshaft Adjustment Actuators F366 – F373

The camshaft adjustment actuators are electromagnetic solenoid-type actuators. Two actuators are used per cylinder. One actuator moves the cam element on the camshaft for large valve lift. The other actuator resets the cam element for small valve lift.

Each actuator is attached externally to the cylinder head cover by a bolt. They are sealed with O rings. When the actuator is activated by the ECM, a metal pin engages the displacement groove in the cam element, thereby moving the other cam lobe into position.



Design



Function

A solenoid is integrated in the actuator. When the solenoid is activated by the ECM, a metal pin is extended. The solenoid is activated through brief application of battery voltage.

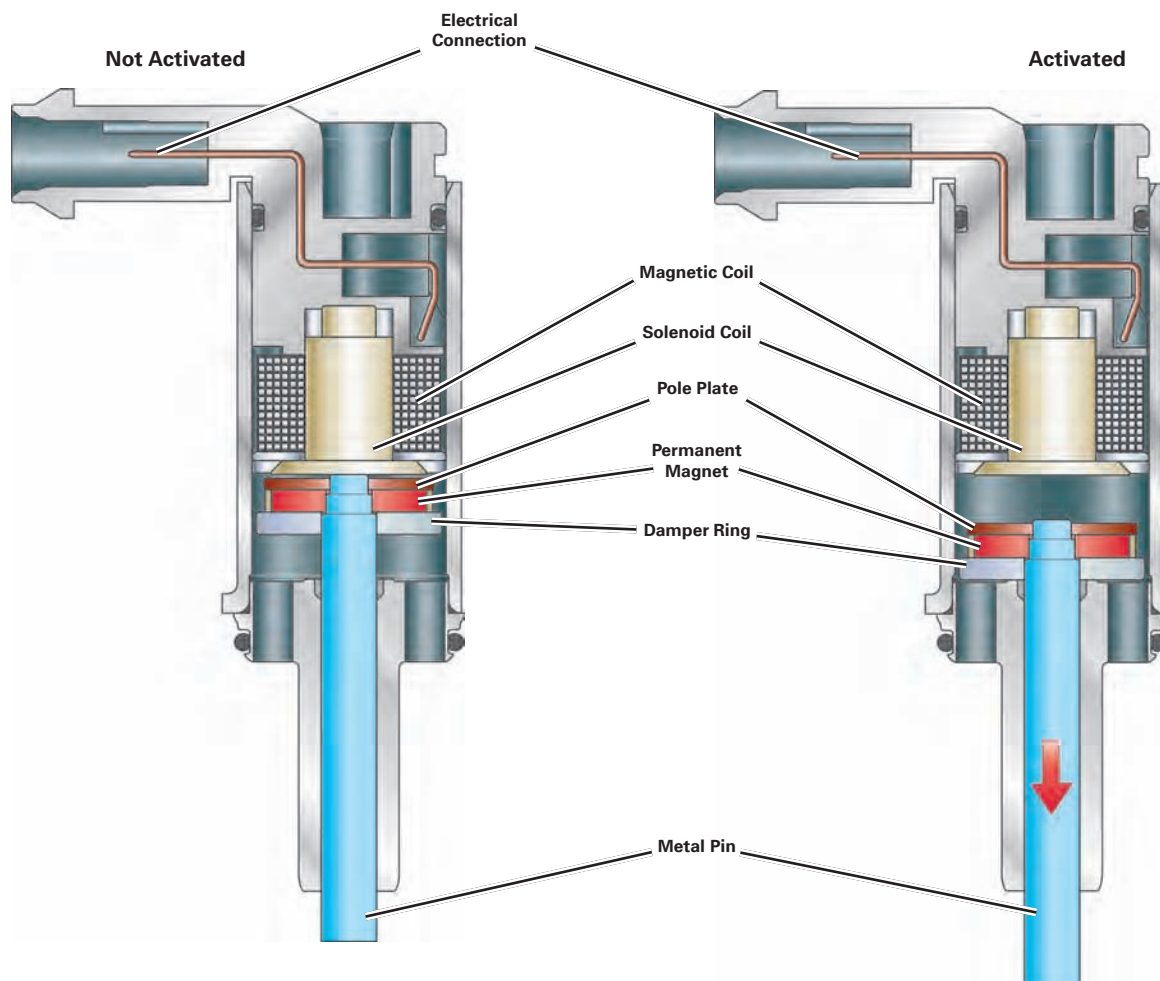
When the metal pin is extended, it is held in position by a permanent magnet on the actuator housing.

Due to the quick extension time (18 – 22 ms), the metal pin undergoes very rapid acceleration. A damping ring near the permanent magnet ensures that the pin does not bounce back or become damaged.

The metal pin extending into the displacement groove then moves the cam element as the camshaft rotates.

The contour of the displacement groove is designed to push the metal pin of the actuator back after just under one revolution of the actuator. The permanent magnet ensures that the metal pin remains in this position. When the permanent magnet pushes the metal pin, voltage is induced in the magnetic coil of the solenoid.

This return signal is registered by the ECM. It can only be generated if the metal pin is pushed back by the displacement groove after the cam element has been moved. The ECM evaluates the signal input as a successful adjustment.



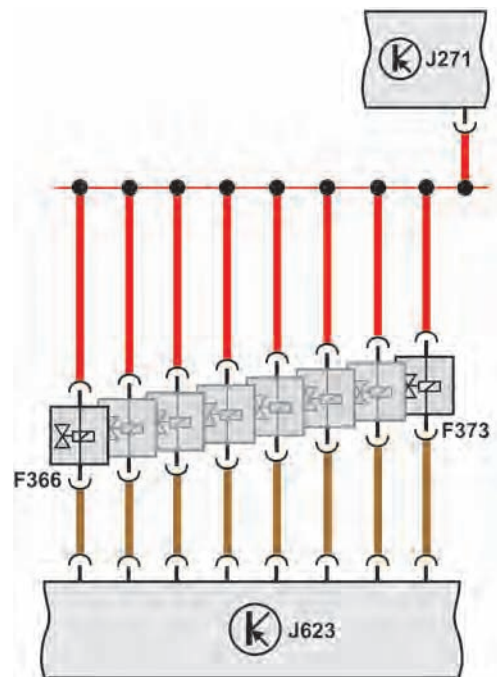
Activation of the Cam Adjustment Actuators

The Camshaft Adjustment Actuators are activated by the ECM, which provides a ground signal. Voltage to the actuators is supplied by Motronic Engine Control Module Power Supply Relay J271. The system is ready for operation above a coolant temperature of 14°F (-10°C).

When the engine is started, the larger contour lobes are in position. Immediately after engine start, the system changes over to the smaller contour lobes.

When the engine stops, the AVS switches back to the large contour cam.

The maximum power input per actuator is 3 amperes.



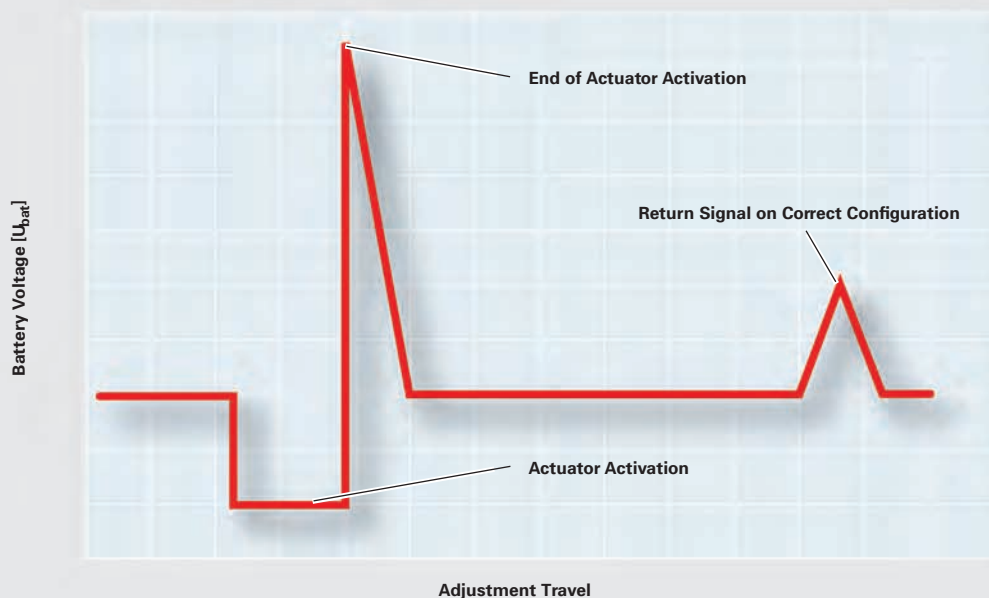
Legend

F366 – F373 Cam Adjustment Actuators

J271 Motronic Engine Control Module Power Supply Relay

J623 Engine Control Module (ECM)

Activation of a Cam Adjustment Actuator

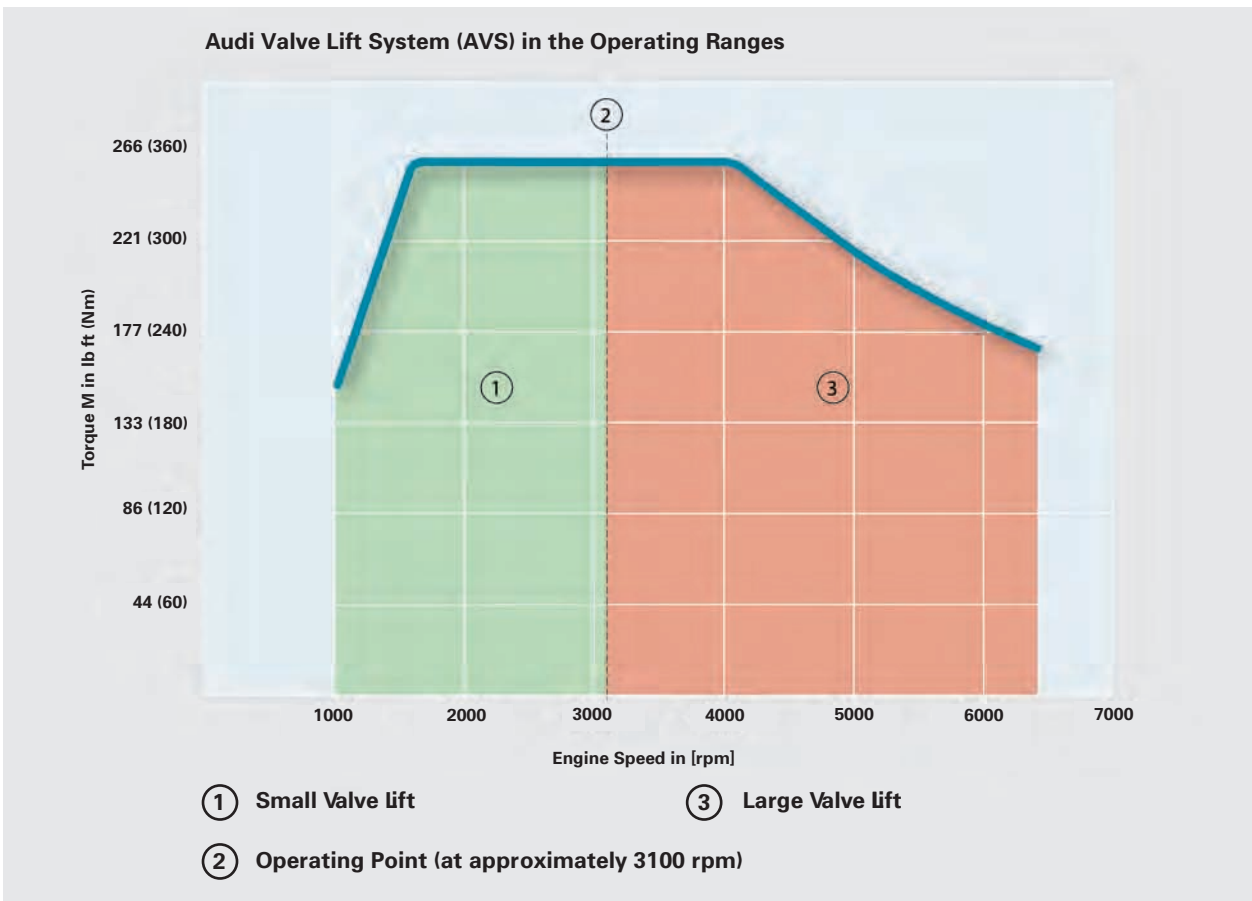


Changing Over Between Working Ranges

The illustration below shows in schematic form the working range of the AVS when the engine is at operating temperature.

It can be seen that the small valve lift is used up to medium engine speeds of approximately 3100 rpm.

In the engine speed range required for change-over to large valve lift, the intake manifold flaps are also opened wide.



Note



This illustration shows an example of a torque curve and AVS operating point. Both are dependent on the current ECM software version, and can change in the course of ongoing model development.

Self-Diagnostics

The engine self-diagnostics check the mechanical function of the cam adjustment actuators (changeover to the other cam lobe contour) and the system's electrical connections.

A system test is performed after the engine is started. The ECM activates each actuator for this purpose.

Both configurations are tested and evaluated. This system test is audible and is performed whenever the engine is started. System failure will result in corresponding DTC entries.

Depending on the nature of the fault, the driver may notice a slight variation in engine idling speed or a different engine response under acceleration.

How the System Responds to Faults

If one or more actuators fails, the ECM will initially attempt (several times) to change over to the other cam. If no adjustment is made, the cam elements that cannot be adjusted remain in position.

All other cam elements are changed over to the large cam. They then remain in this position while the engine is running. The next time the engine is started, another attempt is made to adjust all cam elements.






Activation of the Warning Lamps

Exhaust emissions do not deteriorate due to system failure and because virtually no adverse handling effects may result, neither Electronic Power Control Warning Lamp K132 nor Malfunction Indicator Lamp K83 is activated. However, corresponding DTC entries are generated.

Vehicle self-diagnostics		01 - Engine electronics	
004.01 - Interrogate fault memory		EV_ECM20AVS_X1	
1 Fault detected			

SAE code	Text	Status
P11A100	Cam adjuster "A", cylinder 1 Electrical fault/open circuit	active/ static

Ambient conditions

Oil Circulation System

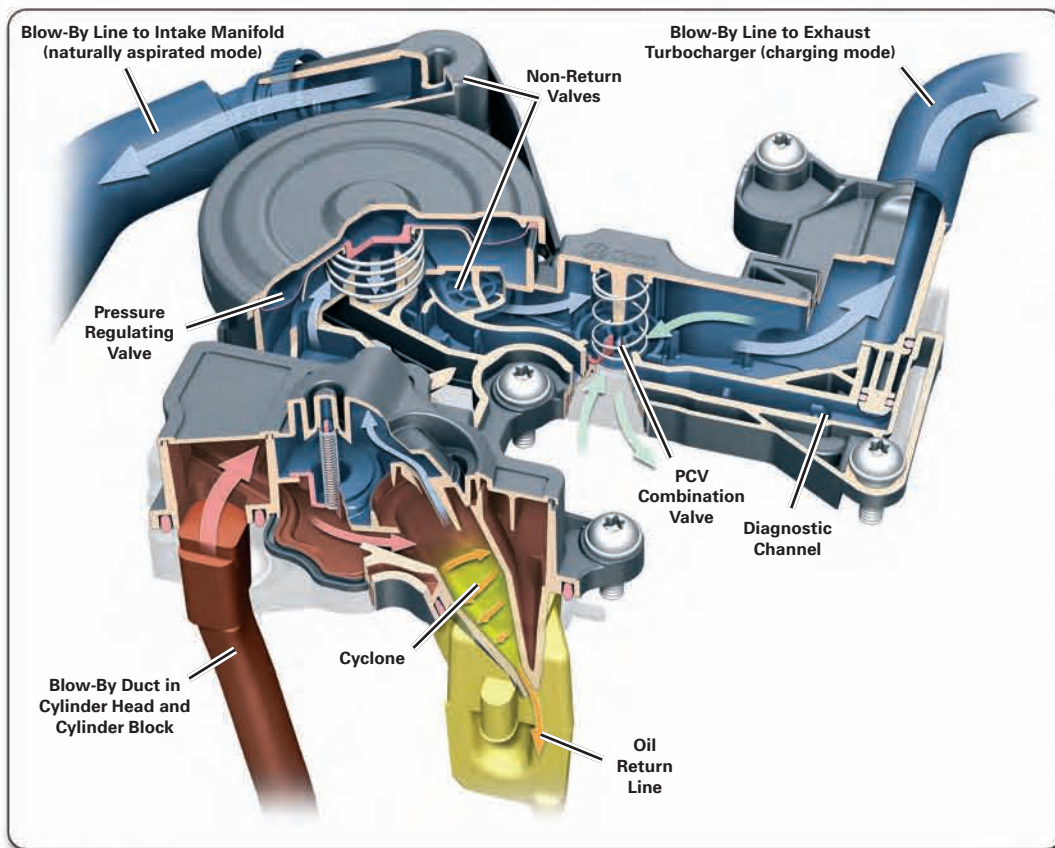
Positive Crankcase Ventilation

One of the goals in designing this new engine was to provide greater driver, passenger, and pedestrian safety in the event of a collision. For instance, the more compact design of the components above the cylinder head cover provides more clearance between the engine and hood. This translates to a larger crumple zone for the dissipation of energy upon impact.

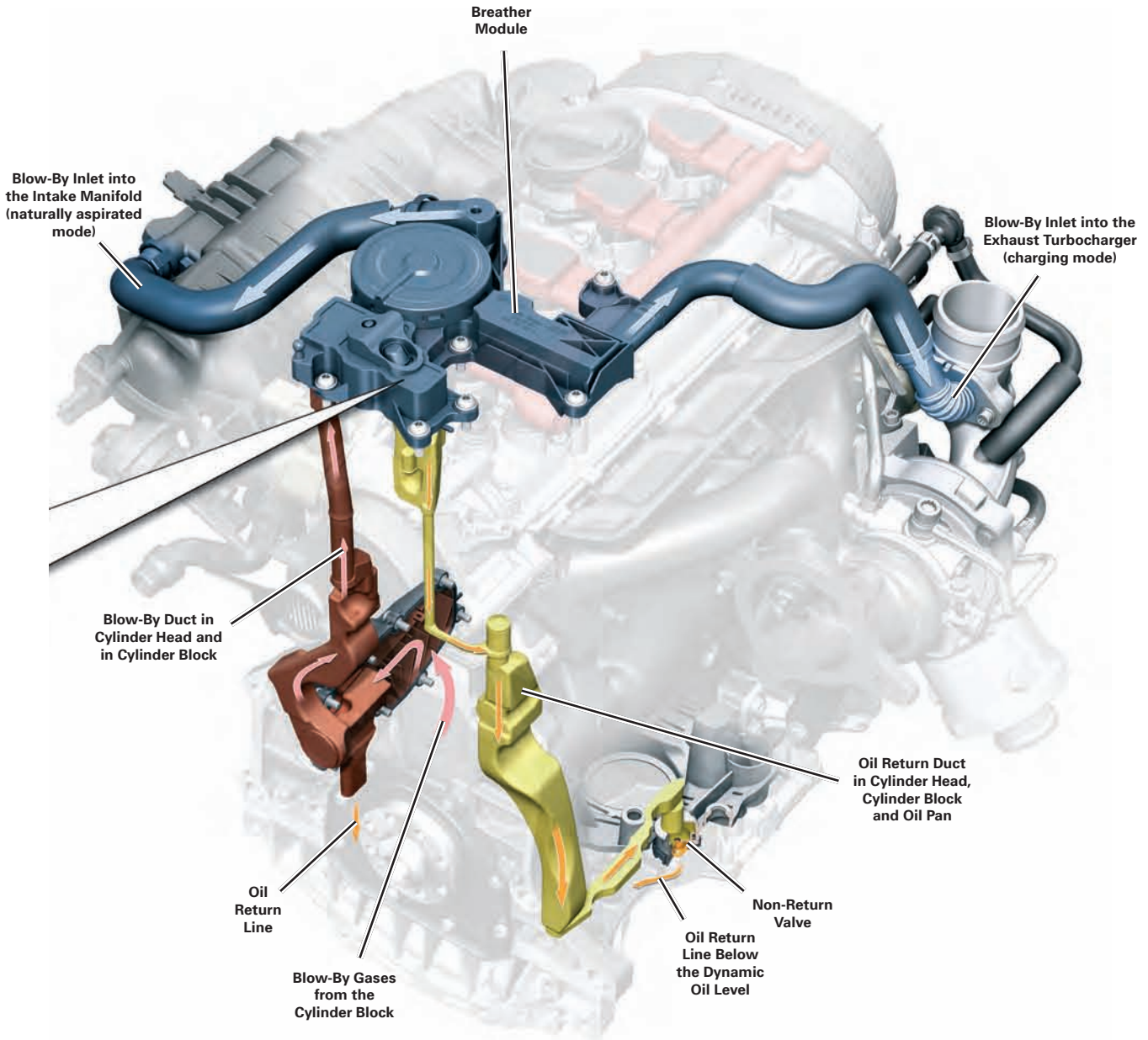
The following components were modified to achieve this goal:

- Blow-by gas duct integrated in the cylinder crankcase
- Fine oil separator module with integrated pressure regulating valve, non-return valve and positive crankcase ventilation valve (PCV valve)

Valve Unit



Overview



Reference



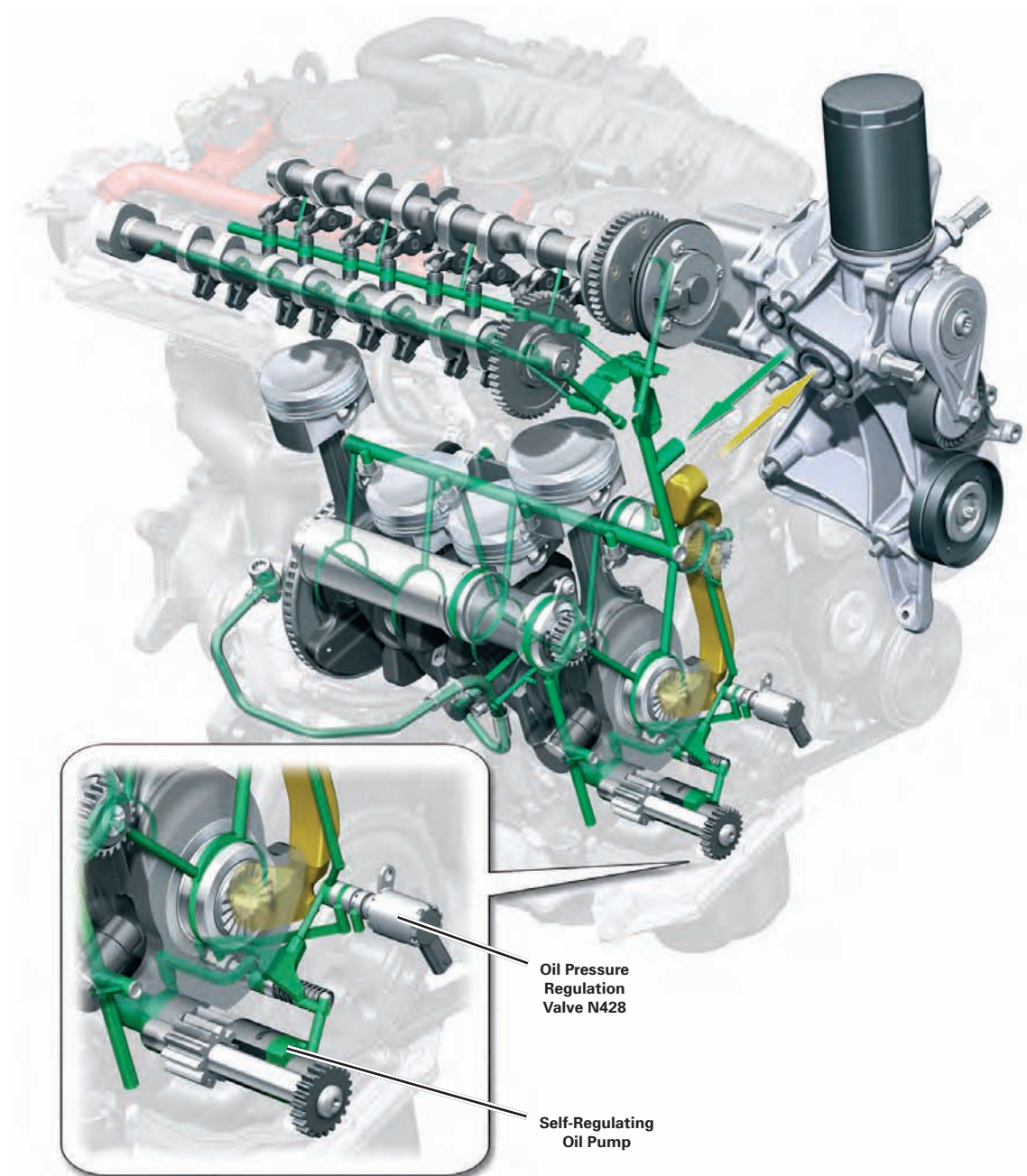
The components are positioned differently, but have retained the same functions as on the 1.8L TFSI engine (base engine). For further information, refer to Self-Study Program 921703: Audi 2.0 Liter Chain-Driven TFSI Engine.

Oil Circulation System

Overview

The oil circulation system of the 2.0L TFSI CAEB engine is unchanged from the CCTA/CBFA engine.

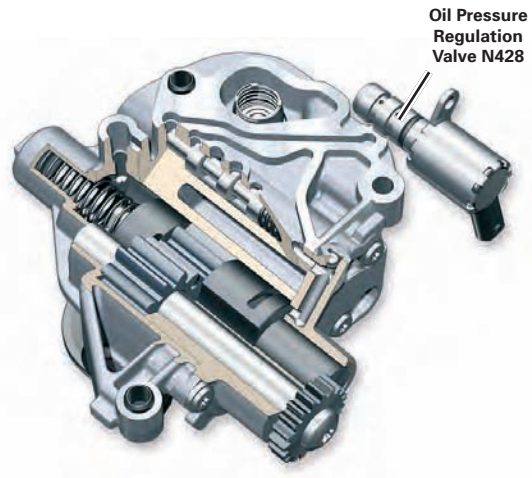
The biggest difference between the two engines is the use of a new self-regulating oil pump on the CAEB engine.



Self-Regulating Oil Pump

A newly developed self-regulating engine oil pump is used on the 2.0L TFSI CAEB engine. The main purpose of this development is to increase pump operating efficiency and in turn, reduce fuel consumption.

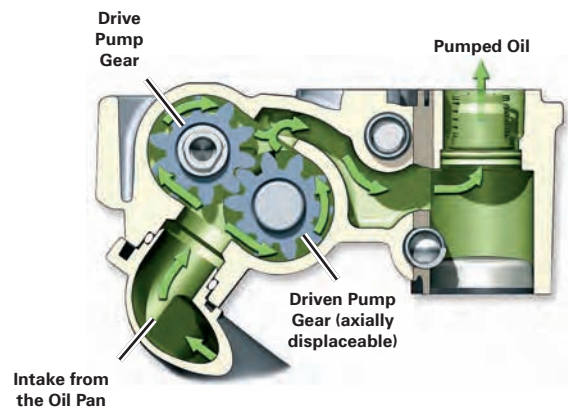
When compared to other self-regulating oil pumps, this design has a more efficient control concept.



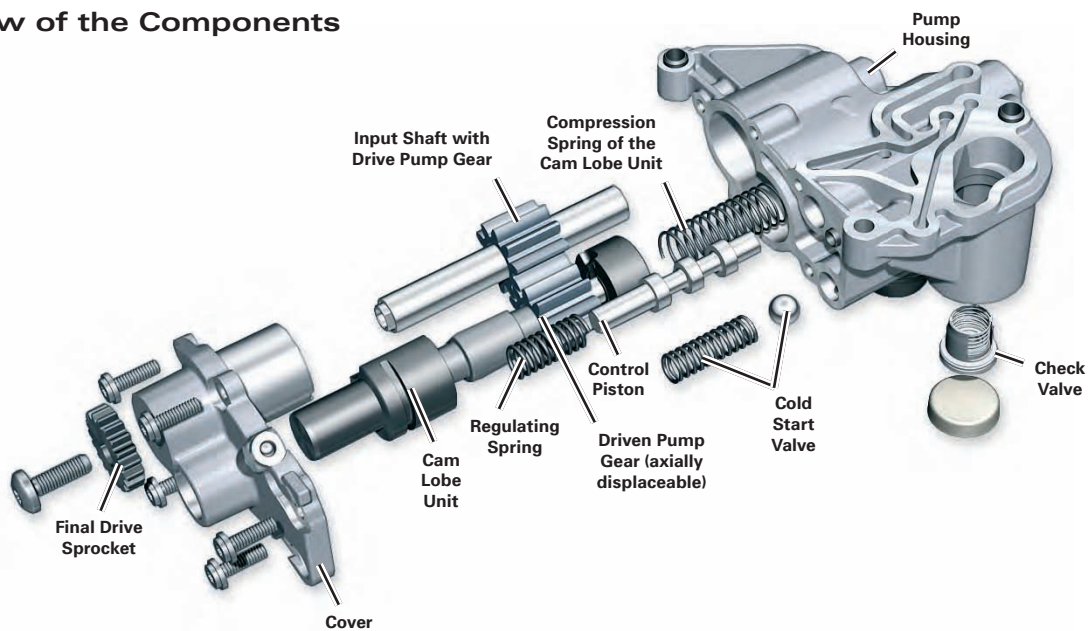
Design

With an external gear pump, the driven pump gear is axially displaceable in relation to the drive gear. This means that the driven gear can move and change the amount the gear lobes mesh with those of the drive gear under certain operating conditions.

By displacing the driven pump gear, the delivery rate and pressure in the oil circulation system can be regulated in a controlled manner.



Overview of the Components



Oil Circulation System

Function

Conventional Method of Control

With a conventional oil pump, the delivery rate increases as the engine RPM increases. The oil consumers in the engine cannot process the excess oil being delivered, so the oil pressure increases.

Previously, pressure limiting took place inside the pump. A mechanical valve opened for this purpose. However, since the pump was still operating at its maximum delivery rate, a portion of the input energy was inefficiently converted to heat.

The concept of the new control system involves two different pressures. The low pressure setting is approximately 26 psi (1.8 bar). The system changes to the high pressure setting, approximately 48 psi (3.3 bar), at an engine speed of approximately 3500 rpm.

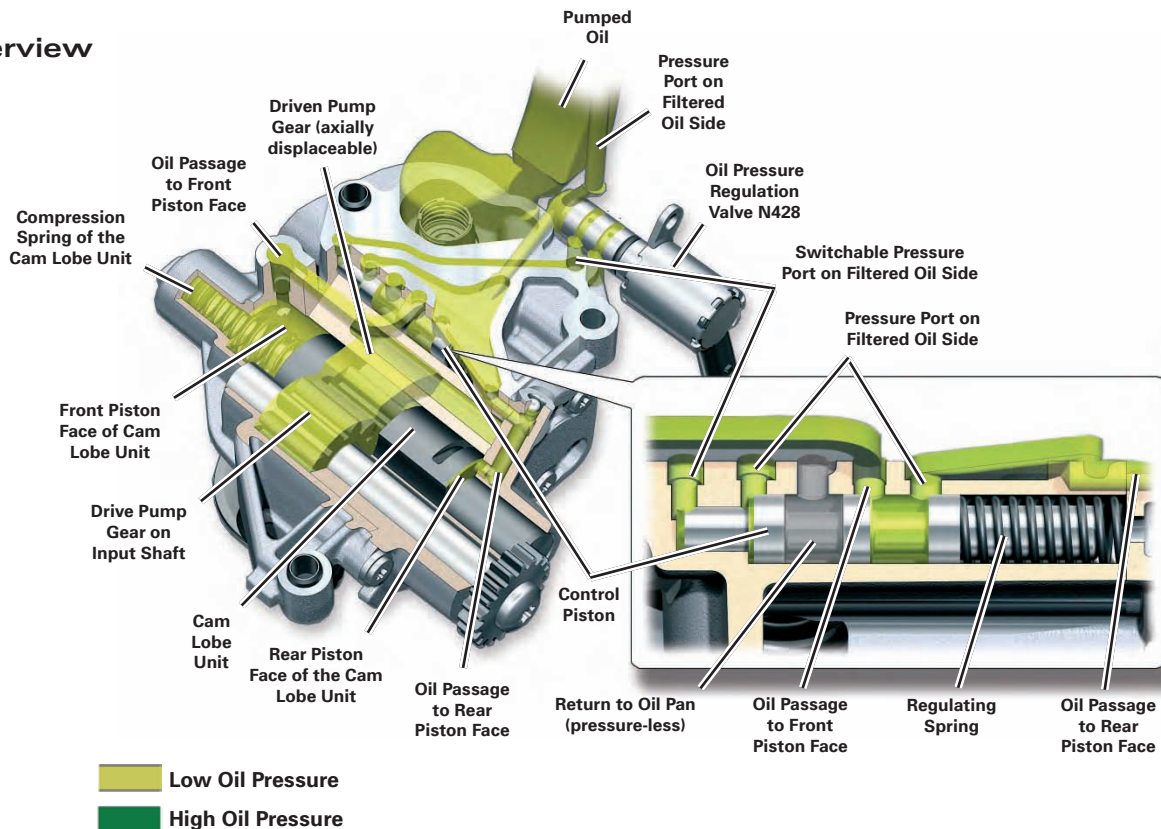
The pressure is regulated by controlling the delivery rate of the pump gears. Oil delivery is controlled to produce exactly the required filtered oil pressure downstream of the oil cooler and oil filter.

This is achieved by axial displacement of the cam lobe unit or in other words, by displacement of the oil pump gears relative to one another. The delivery rate is highest when both pump gears are aligned exactly opposite each other. The greater the axial displacement of the driven pump gear, the lower its delivery rate will be (only oil displaced between the pump gears is conveyed). The pump gear is displaced by the incoming filtered oil pressure acting on the front piston face of the cam lobe unit. A compression spring also acts upon the front piston face of the cam lobe unit.

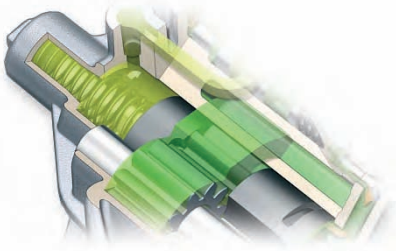
Filtered oil pressure is permanently applied to the rear piston face of the cam lobe unit.

A control piston applies pressure through the pressure port on the filtered oil side to the front piston face of the cam lobe unit. The engine oil pressure that has just been developed is used to counteract the force exerted by the regulating spring. The application of oil pressure is a continuous and dynamic process. The control piston moves continuously in alternating linear directions.

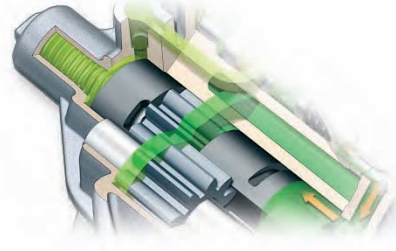
Overview



Positions of the Cam Lobe Unit



No axial displacement: maximum oil flow rate

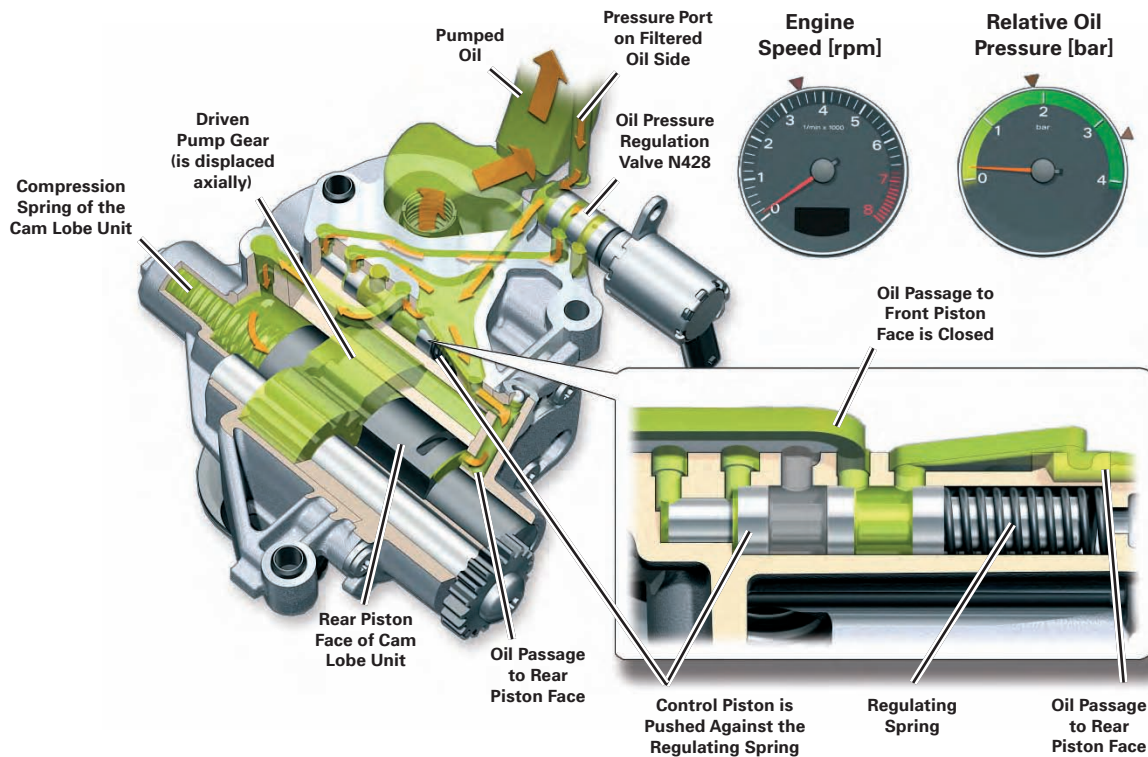


Maximum axial displacement: low oil flow rate

Engine Start-Up

The illustration below shows how the oil pump functions when the engine is started. Engine oil passes through the pressure port on the filtered oil side and impinges on all surfaces of the control piston while flowing to both sides of the cam lobe unit. Oil Pressure Regulation Valve N428 is activated by the ECM and holds the switchable pressure port open so that oil pressure is applied to all surfaces of the control piston.

The cam lobe unit remains in this position. The pump operates at maximum output until the low pressure setting is reached (approximately 26 psi [1.8 bar]). A lower value is also possible when the engine is idling. However, an excessively low value would cause irreparable damage to the engine. Therefore, the oil pressure must be monitored, in this case by Reduced Oil Pressure Switch F378.



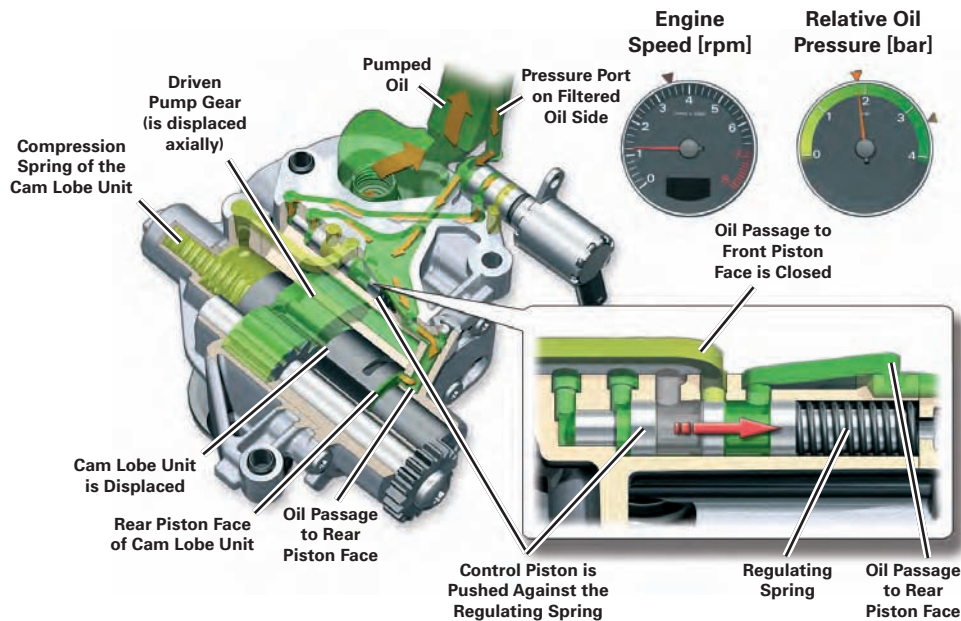
Oil Circulation System

Low Pressure Setting Reached

If engine speed increases, the oil pressure increases slightly and displaces the control piston against the force of the regulating spring. The pressure port to the front piston face of the cam lobe unit closes.

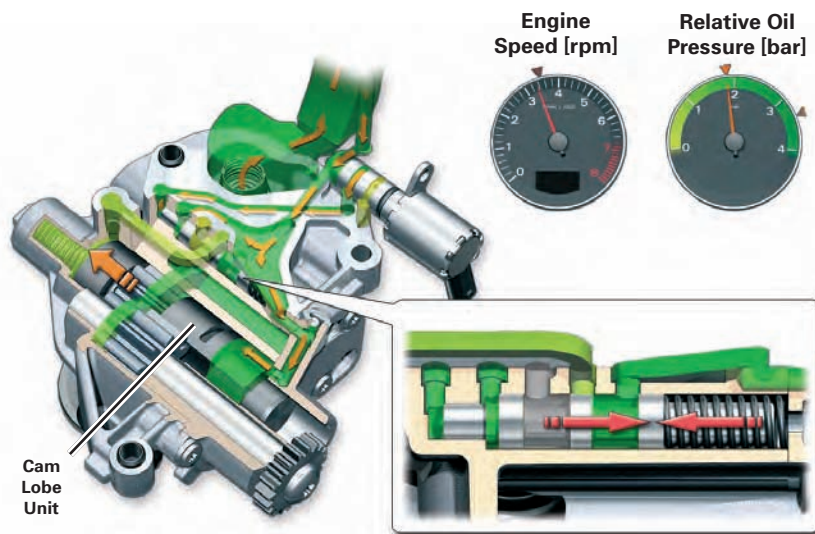
At the same time, the connection to the pressureless return line leading into the oil pan opens. The hydraulic force exerted by the rear piston face of the cam lobe unit is now greater than the spring force.

As a result, the cam lobe unit moves against the force of the compression spring. The driven pump gear is displaced axially relative to the drive pump gear. The volumetric flow rate decreases and adjusts to the engine's oil consumption. By adjusting the volumetric flow rate, the oil pressure is kept at a relatively constant level.



Shortly Before Change-Over to the High Pressure Setting

The cam lobe unit is fully extended.



Change-Over Point to High Pressure Setting

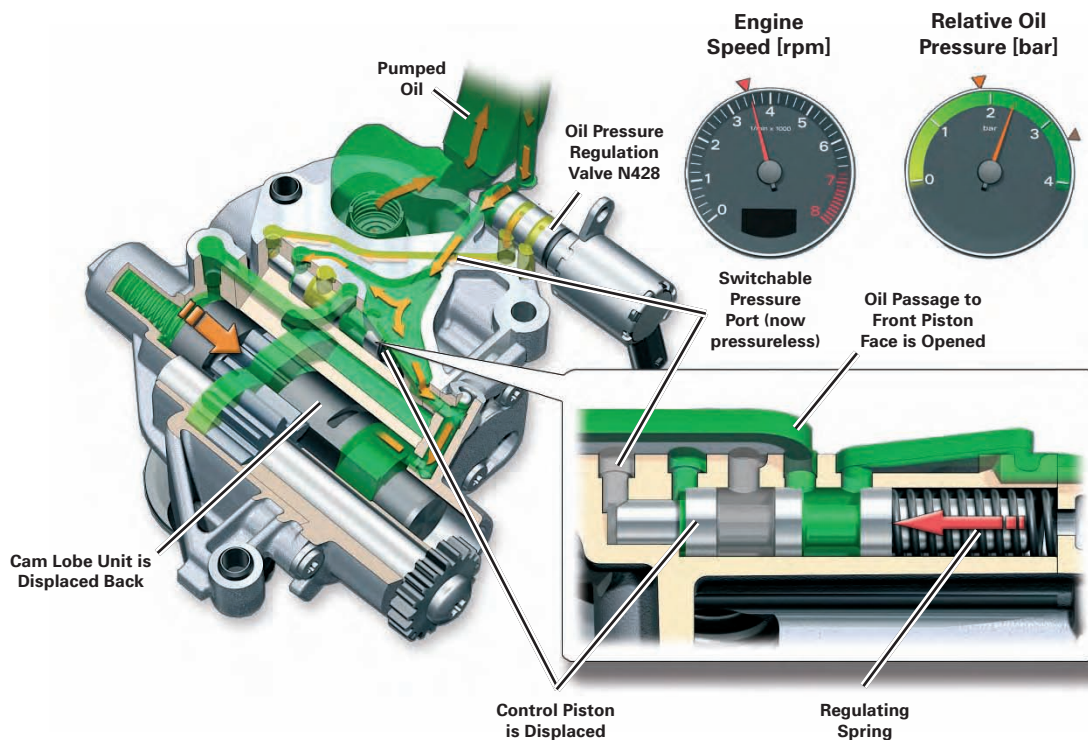
The system changes over to the high pressure setting at an engine speed of approximately 3500 rpm. Oil Pressure Regulating Valve N428 is de-energized for this.

This simultaneously causes the switchable pressure port and the port to the pressureless chamber in the oil pan to close.

Since the surface of the control piston is no longer effective, the force of the regulating spring is now predominant.

The control piston moves far enough to open the port to the front piston face of the cam lobe unit.

The oil pressure acting upon the front piston face and the compression spring push the cam lobe unit back again, so that both pump gears are again almost in parallel with one another and the pump is operating at its maximum delivery rate. The cam lobe unit remains in this position until an oil pressure of approximately 47 psi (3.3 bar) is reached.



Note



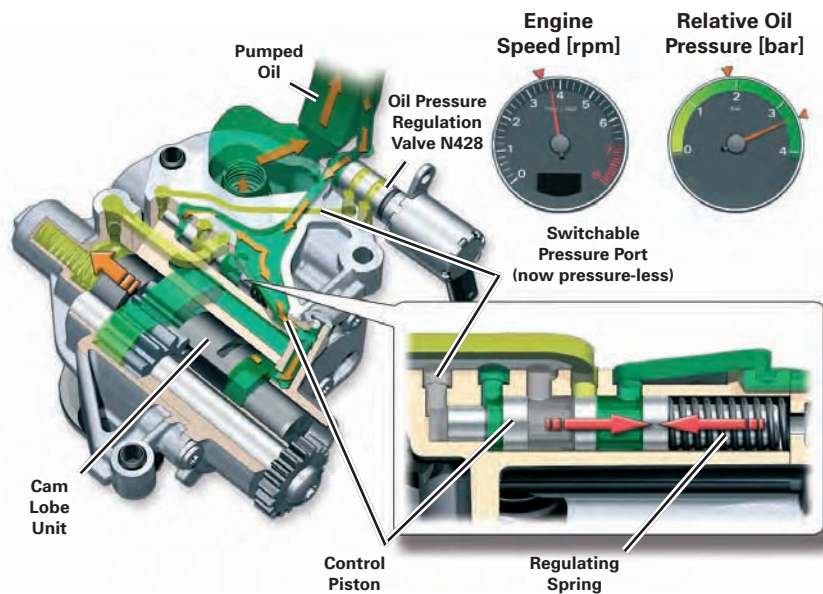
The self-regulating oil pump always operates in the high pressure setting during the first 620 mi (1000 km). This allows for the higher thermal load on components during the break-in period.

Oil Circulation System

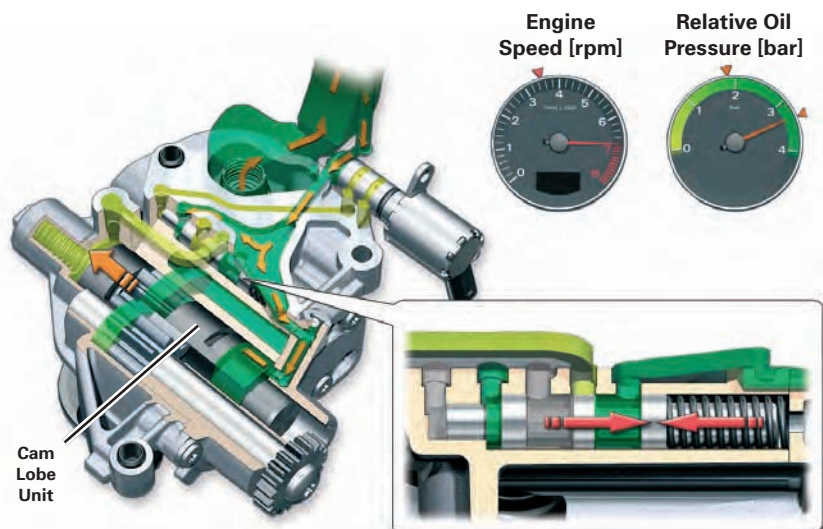
High Pressure Setting is Reached

Oil Pressure Regulation Valve N428 remains de-energized. The force equilibrium between the control piston and regulating spring is maintained by the higher oil pressure (the effective piston surface area is smaller).

As engine speed increases, the cam lobe unit again begins to move (as in the low pressure setting). The change-over to the high pressure setting is registered by 0.3 Bar Oil Pressure Switch F22 (on the oil filter module). In the high pressure setting, the switchable oil passage is kept closed by Oil Pressure Regulation Valve N428.

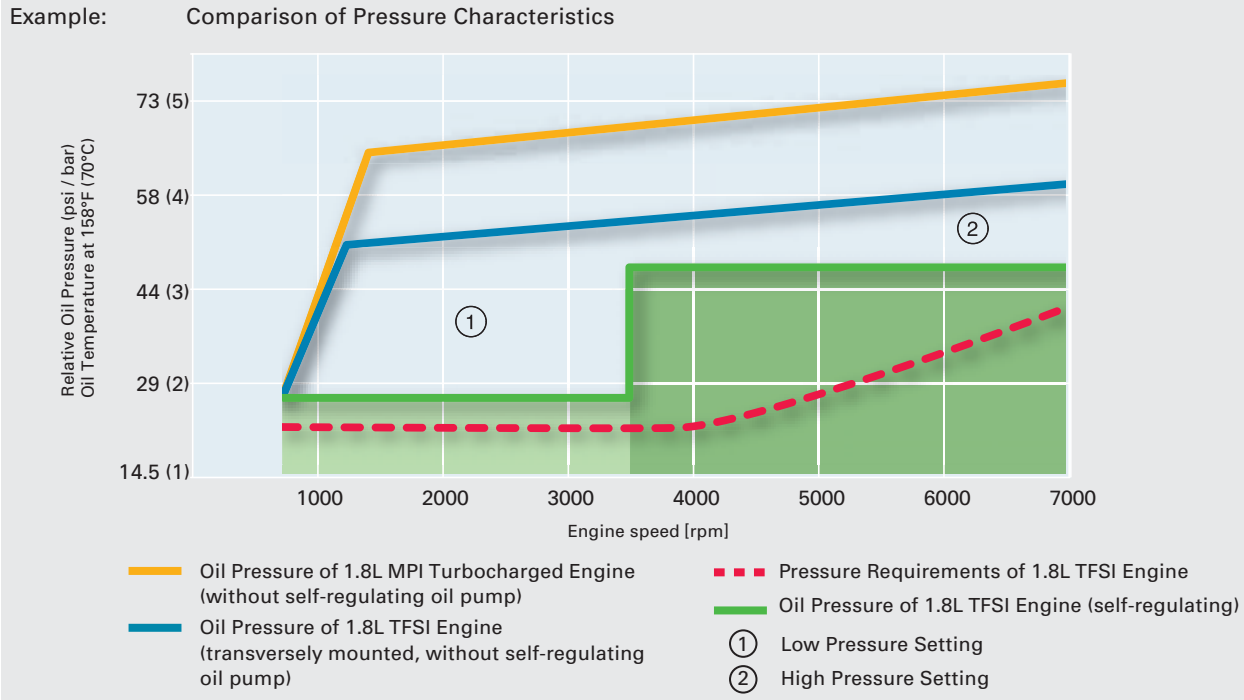


Cam Lobe Unit



Oil Pressure Switch

One or two oil pressure switches are used, depending upon whether the engine is equipped with a self-regulating oil pump. Oil pressure switches are generally mounted on the oil filter module.



Engine Without Self-Regulating Oil Pump

Only Oil Pressure Switch F22 is used on engines not equipped with a self-regulating oil pump. However, this switch has a different part number (different oil pressures are measured).



Engine With Self-Regulating Oil Pump

The self-regulating oil pump uses two oil pressure switches — F22 and Reduced Oil Pressure Switch F378. F378 is located above Oil Pressure Switch F22.



Reference

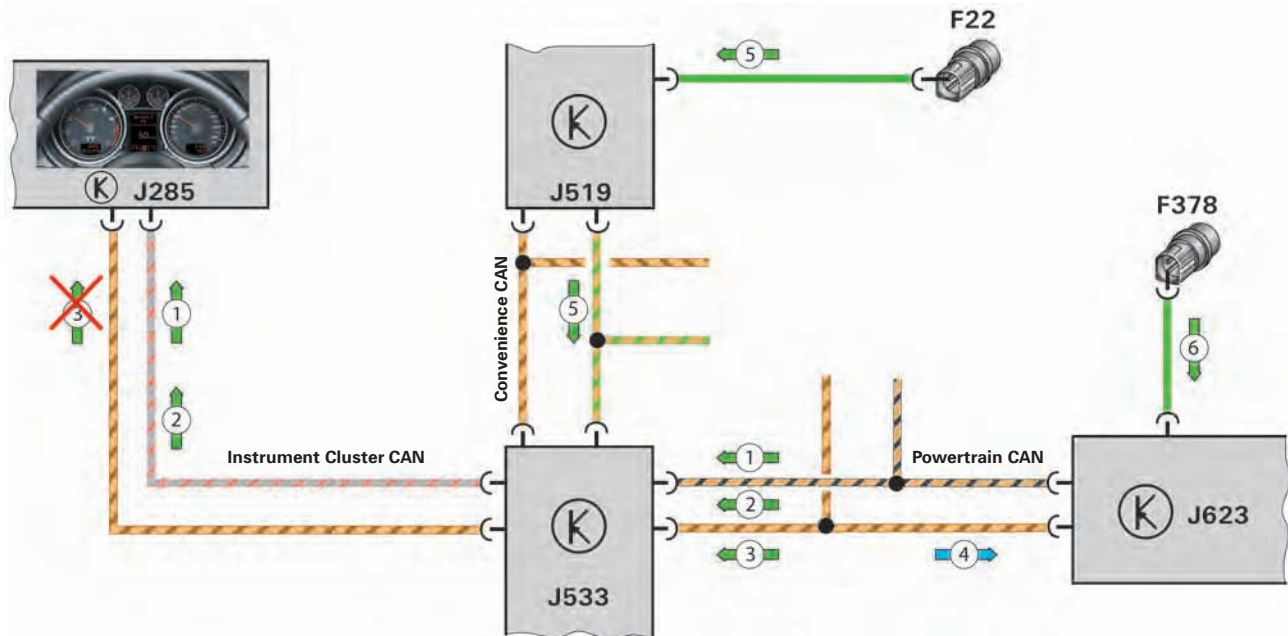


For information on the design of the oil filter module, please refer to Self-Study Program 921703 Audi 2.0 Liter Chain-Driven TFSI Engine.

Oil Circulation System

Oil Pressure Monitoring

On engines with a self-regulating oil pump, oil pressure is monitored by two oil pressure switches. This is necessary because two different oil pressures are used.



Legend

- ① Warning bit "red oil can"
- ② 2 text bits
- ③ Change-over bit = 1
- ④ Switch bit
- ⑤ Signal from Oil Pressure Switch F22
- ⑥ Signal from Reduced Oil Pressure Switch F378

- F22 Oil Pressure Switch
- F378 Reduced Oil Pressure Switch
- J285 Instrument Cluster Control Module
- J519 Vehicle Electrical System Control Module
- J533 Data Bus On-Board Diagnostic Interface
- J623 Engine Control Module (ECM)

Functions and Signals of the Oil Pressure Switch

The two oil pressure switches serve to monitor the oil pressure. Reduced Oil Pressure Switch F378, which is connected directly to the ECM, checks for the presence of oil pressure.

Oil Pressure Switch F22 monitors the high-pressure level of the self-regulating oil pump, provided that it is operating in the high pressure setting.

Signals Generated by the Oil Pressure Switches

Both oil pressure switches are evaluated by the ECM. Earlier versions used a single-stage oil pump and the oil pressure switch was read and evaluated by Instrument Cluster Control Module J285.

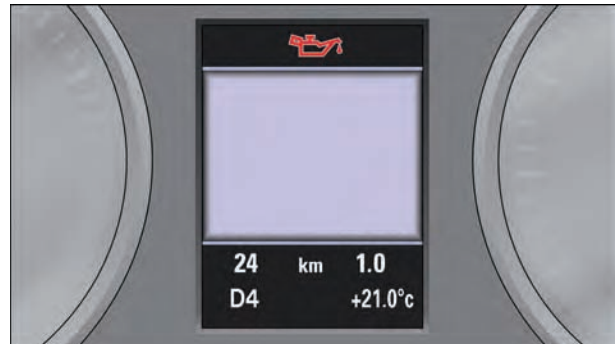
Oil Pressure Switch F22 of the 2009 Audi A4 is read by Onboard Power Supply Control Module J519 and made available to Engine Control Module J623 via the powertrain CAN data bus. The oil pressure switches are normally-open contacts, connecting to ground as soon as the required oil pressure is developed.

Oil Pressure Monitoring

In the ECM, oil pressure switches are monitored at engine ON and validated at engine OFF.

Validation at Engine OFF

There should NOT be a signal from a closed oil pressure switch when the engine is switched OFF. If there is, an electrical fault has occurred. At terminal 15 ON, a warning is indicated in the Driver Information System display ("red oil can" together with the fault text "Shut off engine and check oil level").



Warning at Engine ON

Oil pressure switches are monitored above a defined engine speed threshold, dependent on oil temperature.

The oil pressure switches are generally monitored when the engine is cold (up to 140°F [60°C]) and when the engine is idling. When the engine is at operating temperature, oil pressure switches are only monitored at high engine speeds. If a switch is not closed, the warning "red oil can" is indicated together with the fault text "Shut off engine and check oil level" in the Driver Information System display.

Oil Pressure Switch F22 is monitored as soon as the self-regulating oil pump is operating in the high pressure setting and engine speed exceeds a value computed from the characteristic map (dependent on oil temperature).

If the switch is identified as being "not closed," Engine Electronics Indicator Lamp K149 is activated. Engine speed is limited as well. Engine speed is indicated in the instrument cluster as text and a yellow engine speed symbol.

Fault Analysis Options

A diagnosis is made in the ECM by the oil pressure monitoring function.

The status of Oil Pressure Switch F22 can be viewed under Address Word 09, MVB 28 using a VAS Scan Tool.



Note

Text messages are only displayed for "Validation at engine OFF" and "Warning at engine ON" in vehicles with a Highline instrument cluster.

SULEV 2.0L TFSI Engine

Introduction

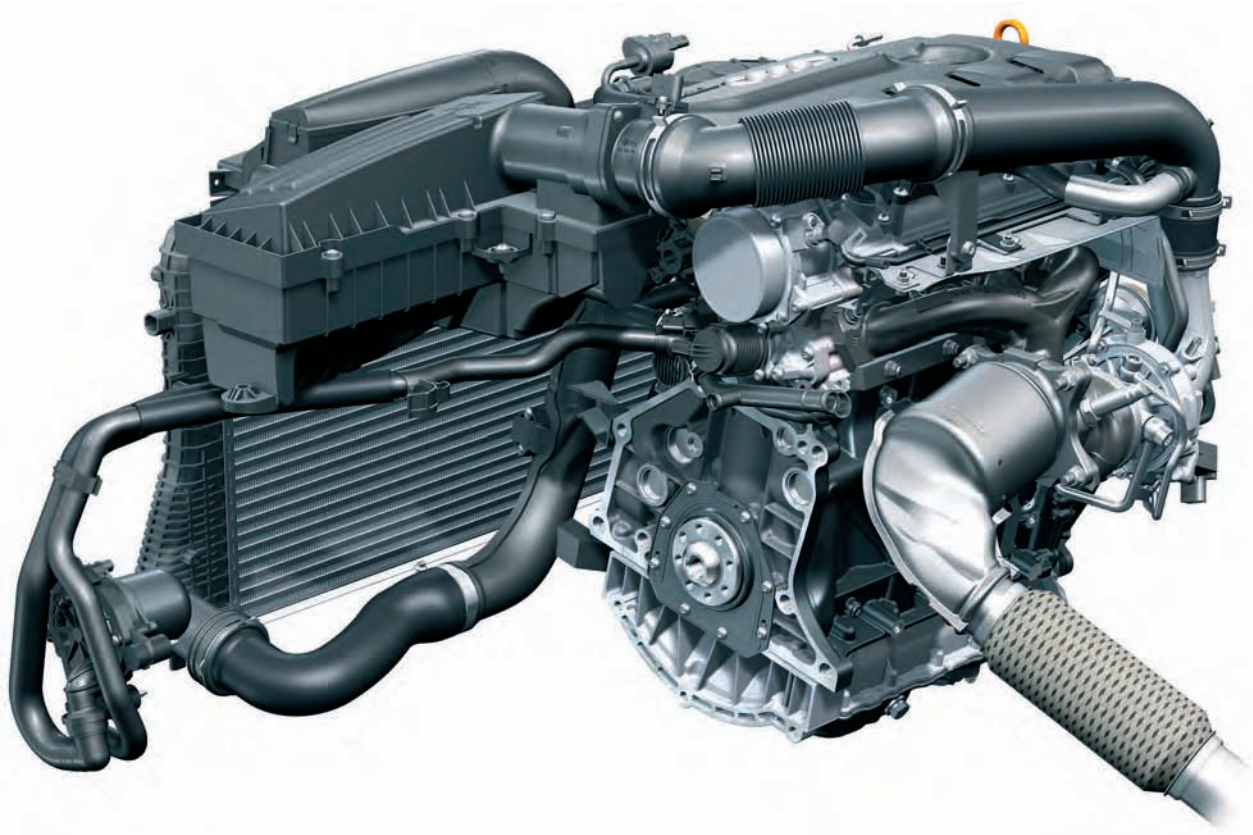
With the introduction of the 2.0L CAEB engine, Audi was able to combine direct fuel injection, AVS, and turbocharging while still meeting the stringent ULEV II exhaust emission limits.

However, some states require the even more stringent SULEV exhaust emission standards.

The measures undertaken to comply with the SULEV exhaust emission regulations will be explained in detail on the following pages. The technical descriptions refer to the Audi A3.

To homologate a vehicle for the North American market, the following conditions must be met:

- Compliance with statutory exhaust emission limits
- No hydrocarbon emission from the fuel system
- All exhaust-related systems and components monitored to OBD II requirements
- Compliance with SULEV exhaust emission limits ensured over 150,000 miles (240,000 km) and 15 years



Secondary Air System

To reduce hydrocarbon emissions at the earliest possible stage, fresh air is blown into the cylinder head exhaust ports during the engine start phase.

The system is designed to rapidly develop pressure and achieve a high delivery rate on activation.

The illustration below shows the components of the secondary air system. The following components are new to the system:

- Secondary Air Injection Sensor 1 G609
- Secondary Air Injection Solenoid Valve N112

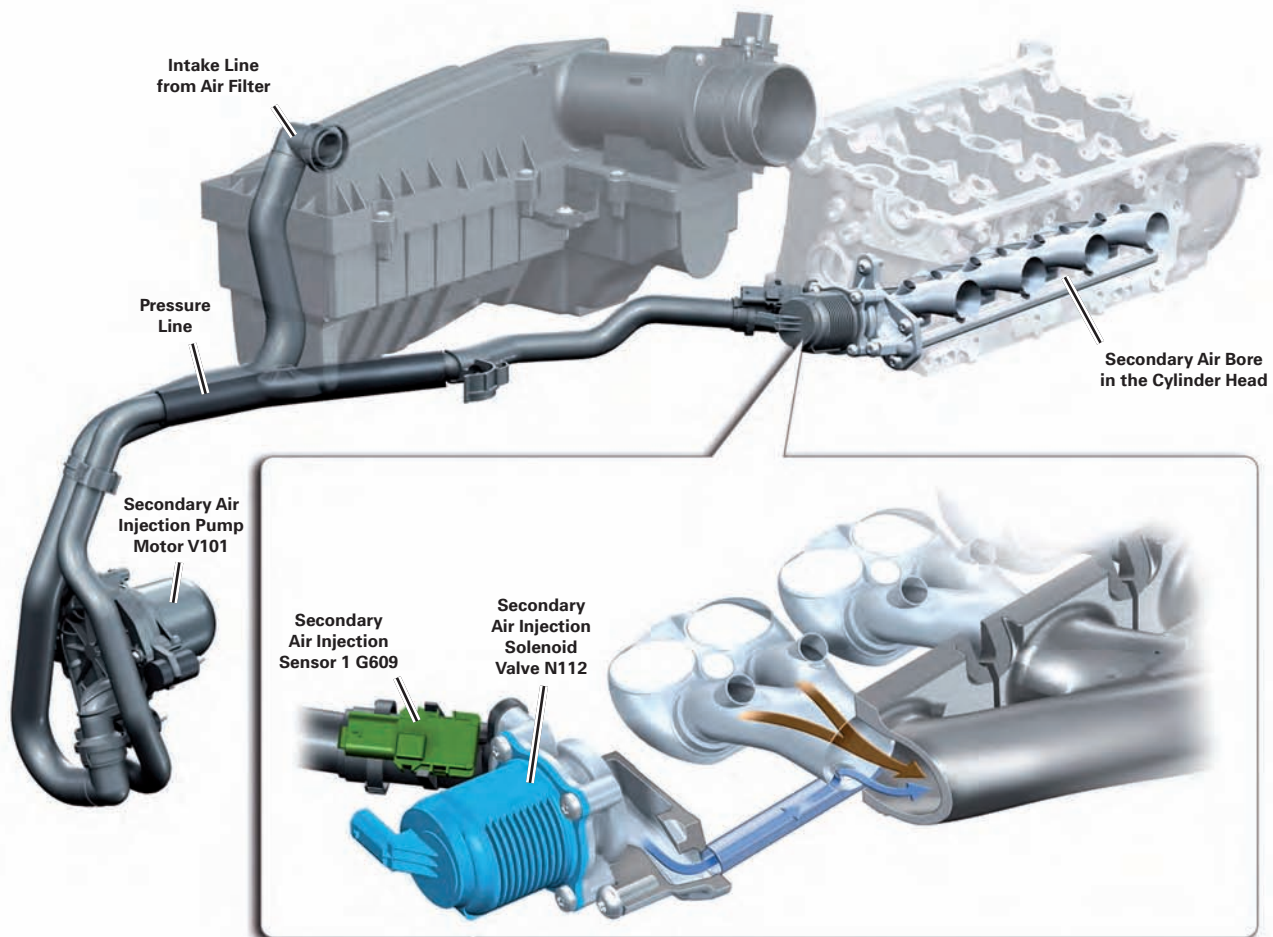
The secondary air pump is positioned above the lowest point of the pressure line system to prevent harmful condensation from collecting in the pump.

If the system is functional, an excess pressure of approximately 2.3 psi (160 mbar) will be achieved in the pressure line while the engine is idling after a cold start. Pressure acting on the sender increases with rising exhaust gas mass flow, depending on how the car is driven (high engine load). Pressure levels of greater than 2.9 psi (200 mbar) above ambient pressure can be achieved.

There is an elongated hole in the cylinder head below the exhaust ports. Secondary air which flows through an elongated hole is drawn directly into the exhaust ports. The proximity of exhaust ports to the exhaust valves is advantageous.

A secondary air reaction occurs immediately, generating the thermal energy required to heat the catalytic converter.

Overview of the Components

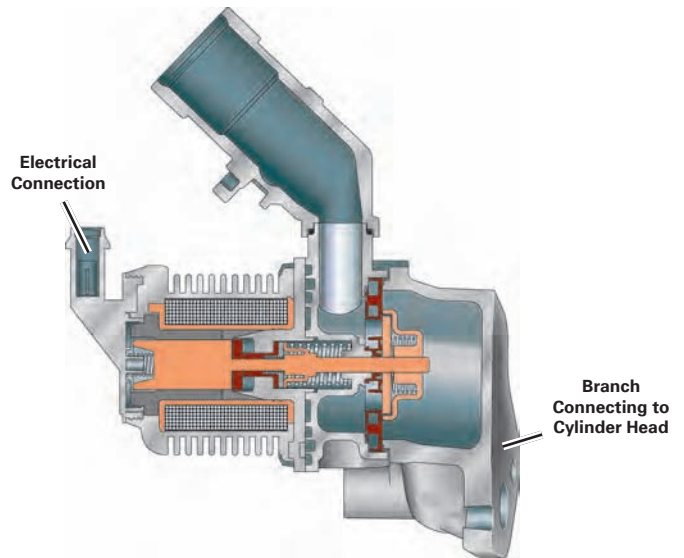


SULEV 2.0L TFSI Engine

Secondary Air Injection Solenoid Valve N112

Unlike earlier valves, the newly developed Secondary Air Injection Solenoid Valve N112 operates electrically. It is mounted directly to the cylinder head by bolts. When compared to the pneumatic valves used previously, the secondary air intake valve is extremely rugged.

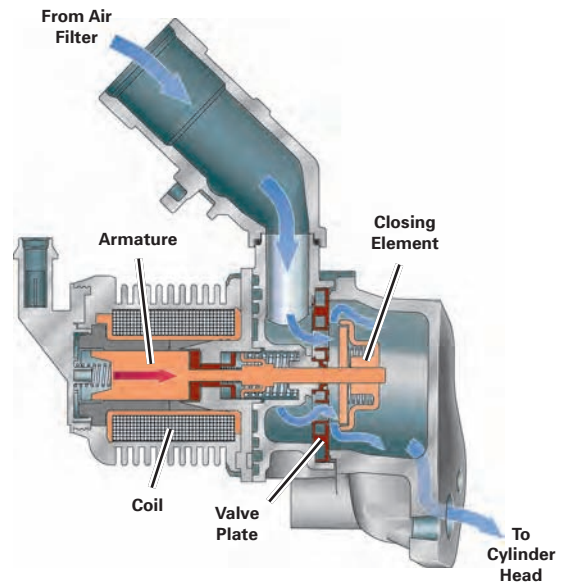
The valve also has a non-return function which prevents exhaust gases from flowing back into the secondary air system, even when the valve is open (illustration at right).



Valve Activated

When N112 is activated by the ECM, secondary air flows through the valve to the cylinder head.

A solenoid lifts the closing element off the valve plate. Secondary air flows through the orifices in the valve plate.



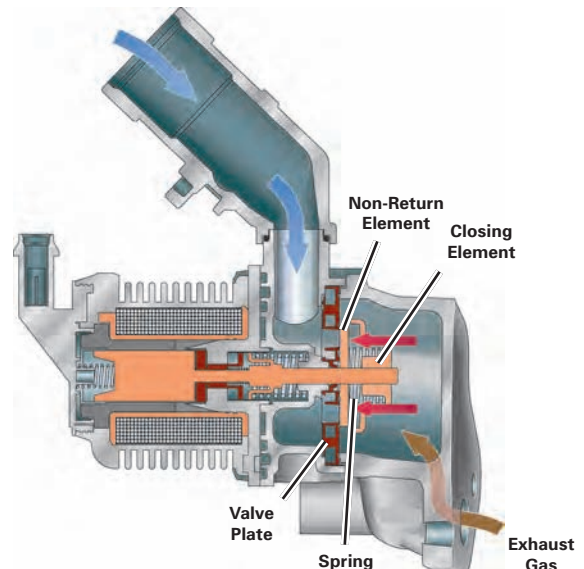
Non-Return Function

When secondary air flows through the valve, the non-return element is pressed down and against a spring, holding the valve open.

If exhaust gases flow back into the secondary air intake valve, secondary air pressure will decrease.

As a result, the non-return element lifts off the closing element with spring assistance and seals the orifices in the valve plate.

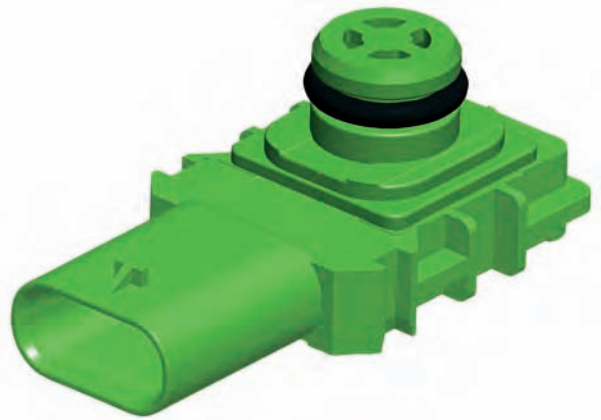
In this way, secondary Air Injection Valve and Secondary Air Injection Pump Motor V101 are protected against possible damage by hot exhaust gases.



Secondary Air Injection Sensor 1 G609

Secondary Air Injection Sensor 1 G609 connects to the pressure line coupling upstream of Secondary Air Injection Valve N112. It supplies the ECM with an analog output signal of between 0.5 and 4.5 V.

Its measurement window is between 7 and 22 psi (50 kPa – 150 kPa).



Signal Utilization

This signal is used for diagnosing the secondary air system. Because the system is relevant to exhaust emissions, legislation requires that it be monitored.

Effects of Signal Failure

A diagnosis is made for the sensor and used to monitor voltage (min-max threshold), and to match ambient pressure and the secondary air pressure sensor (phase 0).

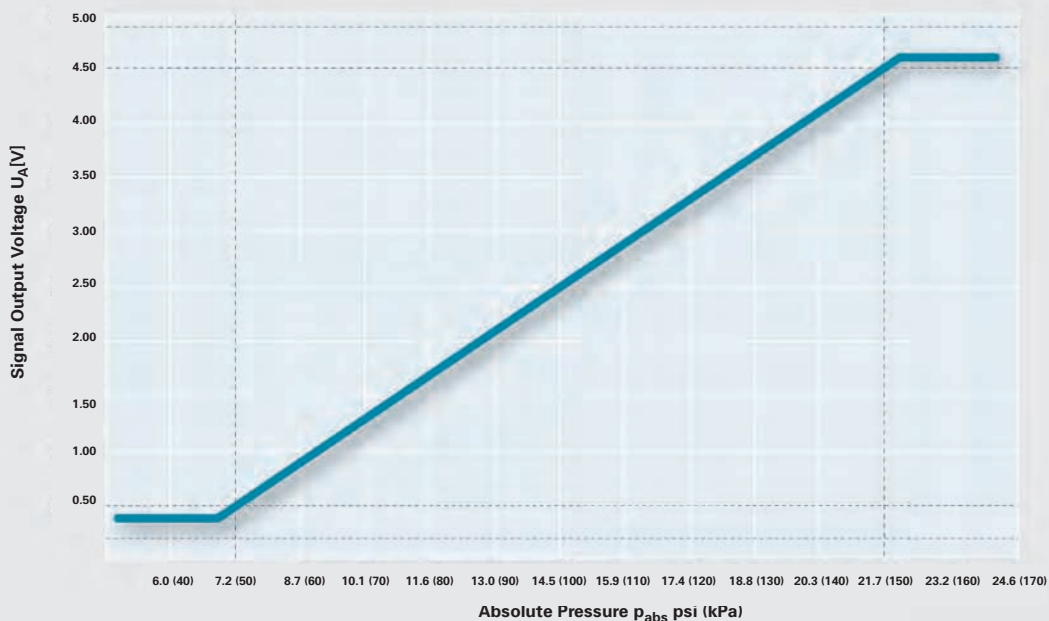
If a fault occurs in a sensor, the system diagnosis result will not be evaluated because the sensor signal will be implausible. However, a diagnosis will still be made.

Diagnostics

If Secondary Air Injection Valve N112 remains closed due to a malfunction, the resulting pressure will be too high. Conversely, the pressure will be too low if a leak occurs in the system upstream of the secondary air injection valve.

In both cases, the corresponding fault memory entries are saved to the ECM, and Malfunction Indicator Lamp (MIL) K83 is activated.

Signal Characteristic of the Secondary Air Pressure Sensor



Testing the System

The California Air Resources Board (CARB) requires that the secondary air system be monitored during the heat-up phase of the catalytic converter.

Previously, the system was monitored using the oxygen sensor. However, this downstream sensor does not become available quickly enough. For this reason, the system is monitored and evaluated for pressure-based secondary air diagnosis by Secondary Air Injection Sensor 1 G609.



Reference

On the next page you will find a diagram showing the individual phases of the secondary air diagnosis process.

Pressure-Based Secondary Air Diagnosis Process

Phase 0

The control module initialization process begins at "ignition on." The signal from Secondary Air Injection Sensor 1 G609 is stored and compared to the signals received from the ambient pressure sensor and the intake manifold pressure sensor.

Phase 1

When the secondary air mass is injected, the pressure within the secondary air system also rises to above atmospheric pressure. This pressure increase is determined by G609. The resulting analog signal is evaluated by the ECM. If the signal exceeds the pre-defined limit, for example due to a blockage in the system or leakage, a DTC entry will be generated. Engine Electronics Indicator Lamp K149 will also be activated. If the system is still in order, the diagnosis procedure will be continued.

Phase 2

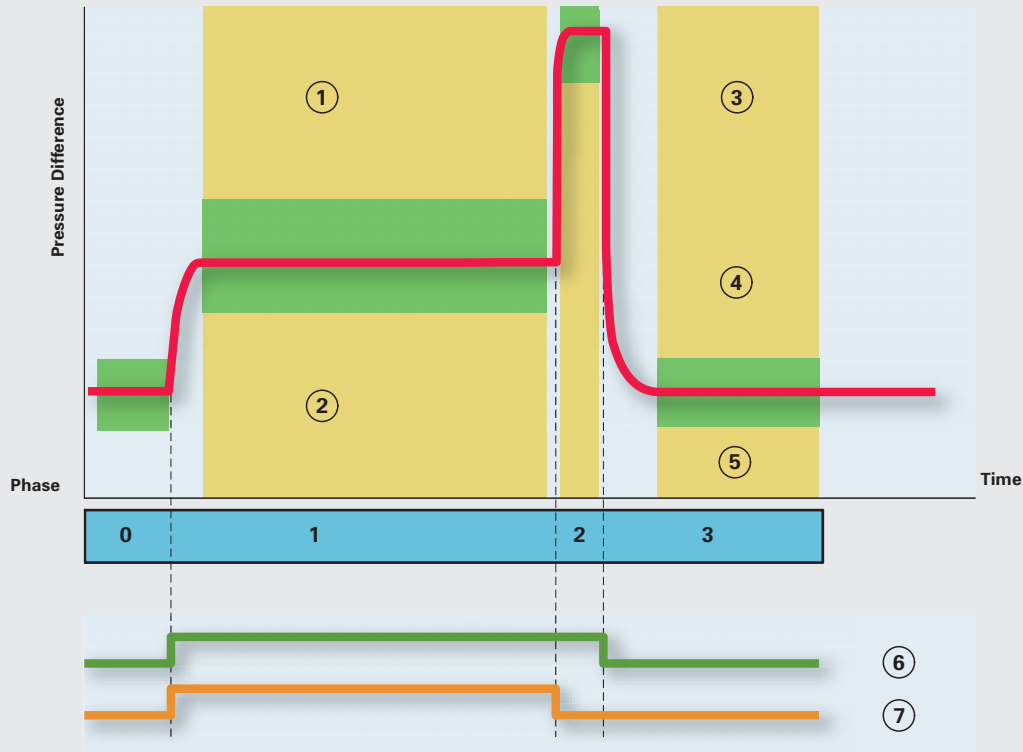
During this phase, Secondary Air Injection Valve N112 is closed and checked for leaks. The value determined by Secondary Air Injection Sensor 1 G609 is evaluated for this purpose.

Phase 3

The secondary air pump is shut OFF and Secondary Air Injection Valve N112 closed. The difference between the actual measured pressure and the stored value generated in phase 0 is evaluated.

A faulty Secondary Air Injection Pump (pump does not shut off) or a faulty Secondary Air Injection Sensor 1 G609 can thus be detected.

Phases of the Secondary Air Diagnosis Process



- ① Blockage (restricted flow)
- ② Reduced Pumping Capacity or a Blockage Upstream of Secondary Air Injection Sensor 1 G609
- ③ Secondary Air Pump Running (does not shut OFF)
- ④ Faulty Pressure Sensor
- ⑤ Faulty Pressure Sensor
- ⑥ Secondary Air Pump Running
- ⑦ Combination Valve 1 Open

SULEV 2.0L TFSI Engine

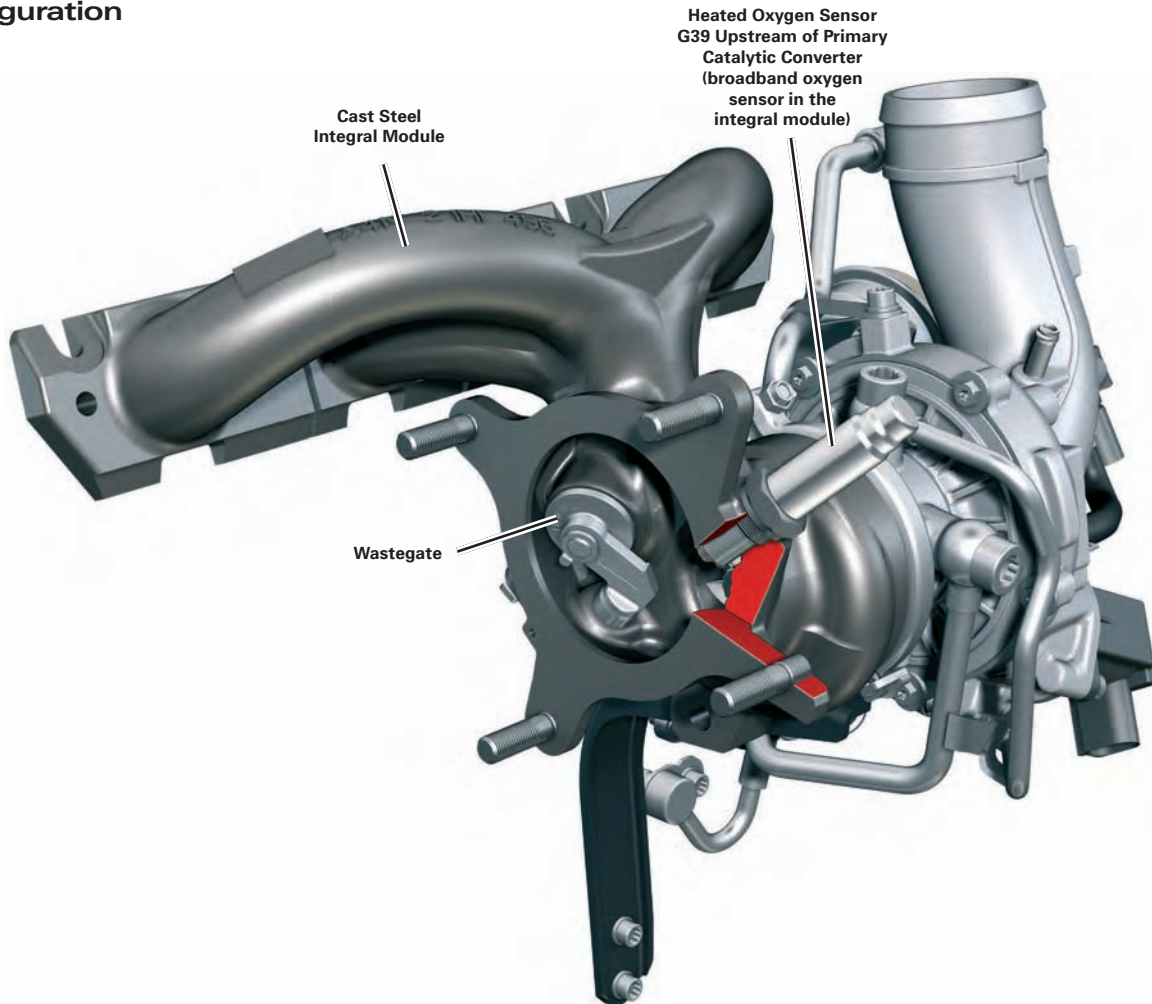
Exhaust Turbocharger

The turbocharger used on SULEV emission level engines is made of cast steel, and not cast iron. Cast steel provides excellent long-term stability. In addition, the components heat up more quickly after engine start-up because they have thinner walls.

Cast steel also allows the oxygen sensor to be positioned inside the turbine housing. This is necessary to ensure the rapid availability of the sensor.

Both air flow and catalytic converter inflow have been greatly improved, reducing the exhaust gas back-pressure upstream of the turbine. Reduced back-pressure means less possibility of turbo-lag while also increasing fuel economy.

Configuration



Catalytic Converter System

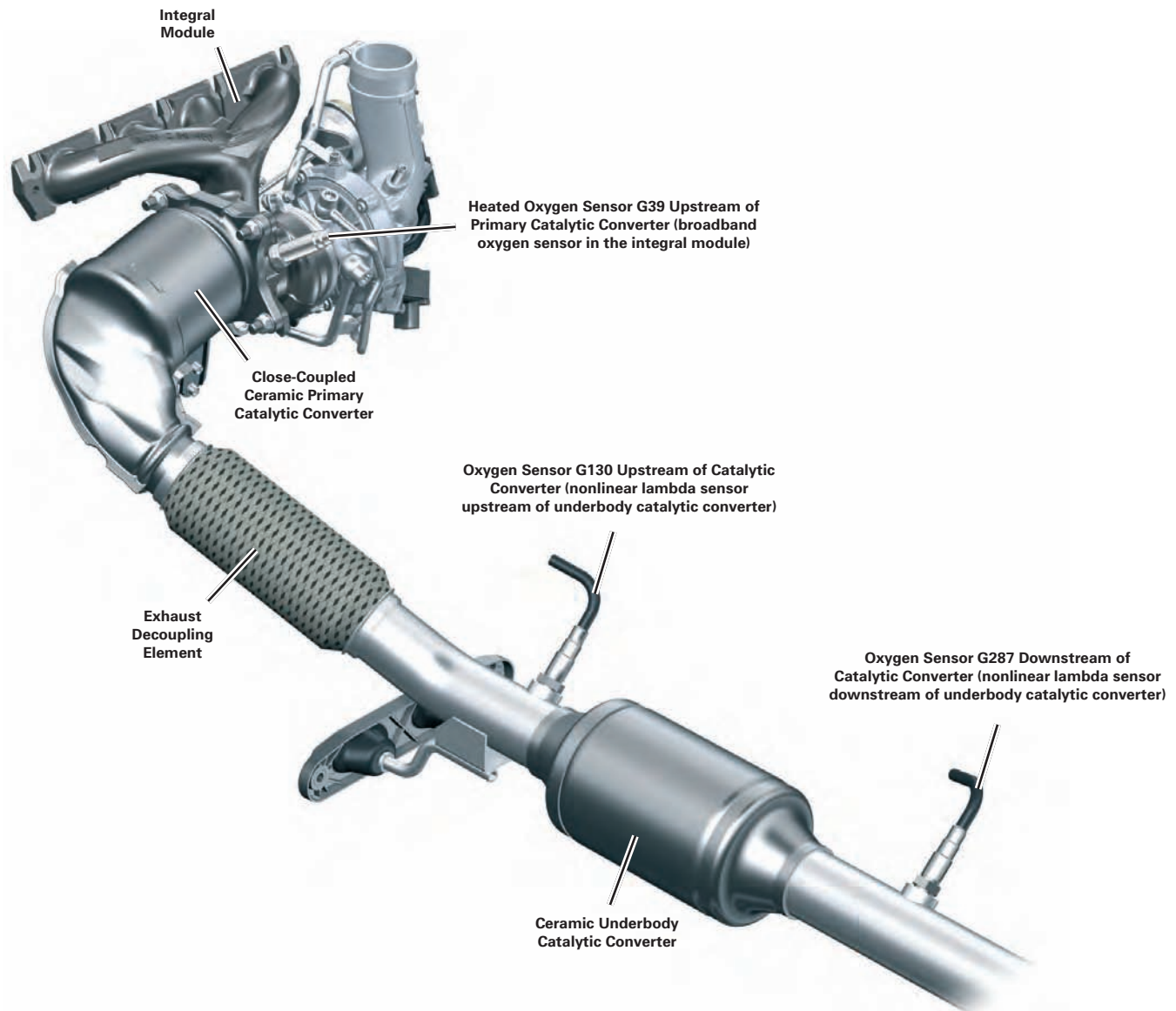
The exhaust system was developed with the following goals in mind:

- Easy compliance with SULEV exhaust emission limits
- High long-term stability over 150,000 miles (240,000 km) and 15 years
- Minimized increase in exhaust back-pressure in catalytic converters with a high cell density
- Reduced light-off time

The primary catalytic converter is designed to comply with statutory emission limits. To achieve this, cell density has been increased and wall thickness reduced.

To minimize light-off time of the primary catalytic converter, it is close coupled to the exhaust turbocharger turbine (directly in the integral module).

Overview of the Components



Oxygen Sensors

The oxygen sensors were designed to minimize the time-to-readiness for the closed-loop operation engine management system.

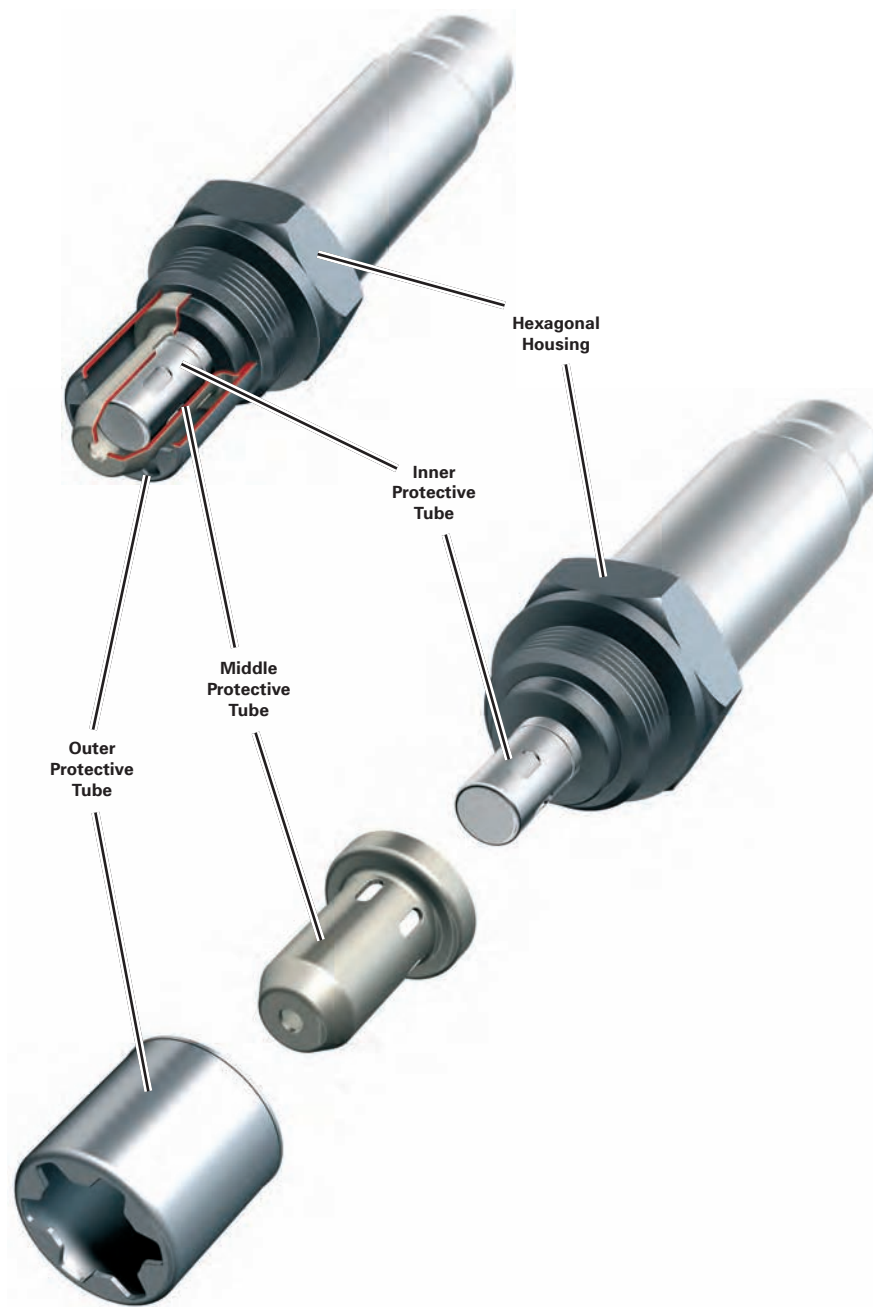
By installing the broadband oxygen sensor in the turbine housing, closed-loop operation can begin only 19 seconds after starting the engine.

Due to the risk of water shock during the broadband oxygen sensor's rapid rate of heating, a special sensor, Oxygen Sensor G39 (LSU4.9), is used here.

G39 is located upstream of the primary catalytic converter. This sensor has an additional triple-layer protective tube.

Two type LSU4.2 nonlinear oxygen sensors are used upstream and downstream of the underbody catalytic converter. They facilitate natural frequency-based closed-loop operation, and allow the primary and underbody catalytic converters to be diagnosed for aging separately.

Design of Heated Oxygen Sensor G39 (LSU4.9)



Natural Frequency Based Oxygen Sensor Control

Task

The task of this system is to maximize utilization of the primary catalytic converter during the conversion of pollutant gases.

Function

Oxygen Sensor G130 LSF4.2 downstream of the primary catalytic converter supplies the ECM with a voltage signal (nonlinear) indicating "rich" or "lean."

Heated Oxygen Sensor G39 LSU4.9 determines a frequency from the flow rate and the condition of the catalytic converter. The ECM provides this frequency with an amplitude indicating whether the mixture is to be "rich" or "lean."

If the primary catalytic converter is supersaturated with oxygen (lean mixture), Oxygen Sensor G130 will send the ECM a nonlinear signal indicating the lean mixture condition.

The mixture is then enriched with fuel until the oxygen has been "displaced" from the catalytic converter. This condition, in turn, is registered by Oxygen Sensor G130 as a nonlinear signal indicating the rich mixture condition.

The mixture is then leaned out by the ECM. If the nonlinear signal is received again, the mixture will again be enriched. The frequency, or period, during which the mixture is enriched or leaned out is variable, being dependent on the gas flow rate (engine load) at that moment. However, aging of the catalytic converter (decrease in conversion rate) also reduces the frequency.

A large proportion of the exhaust gases is converted in the primary catalytic converter. The remaining exhaust gas constituents are then converted to non-toxic gases by the underbody catalytic converter.

Oxygen Sensor 3 Behind Three Way Catalytic Converter G287 (downstream of underbody catalytic converter) operates in much the same way as a conventional linear oxygen sensor.

Its task is to control the fine adjustment of Heated Oxygen Sensor G39. For this purpose, the characteristic curve is corrected by the trimming control in the ECM. It also monitors the conversion process in the catalytic converters.

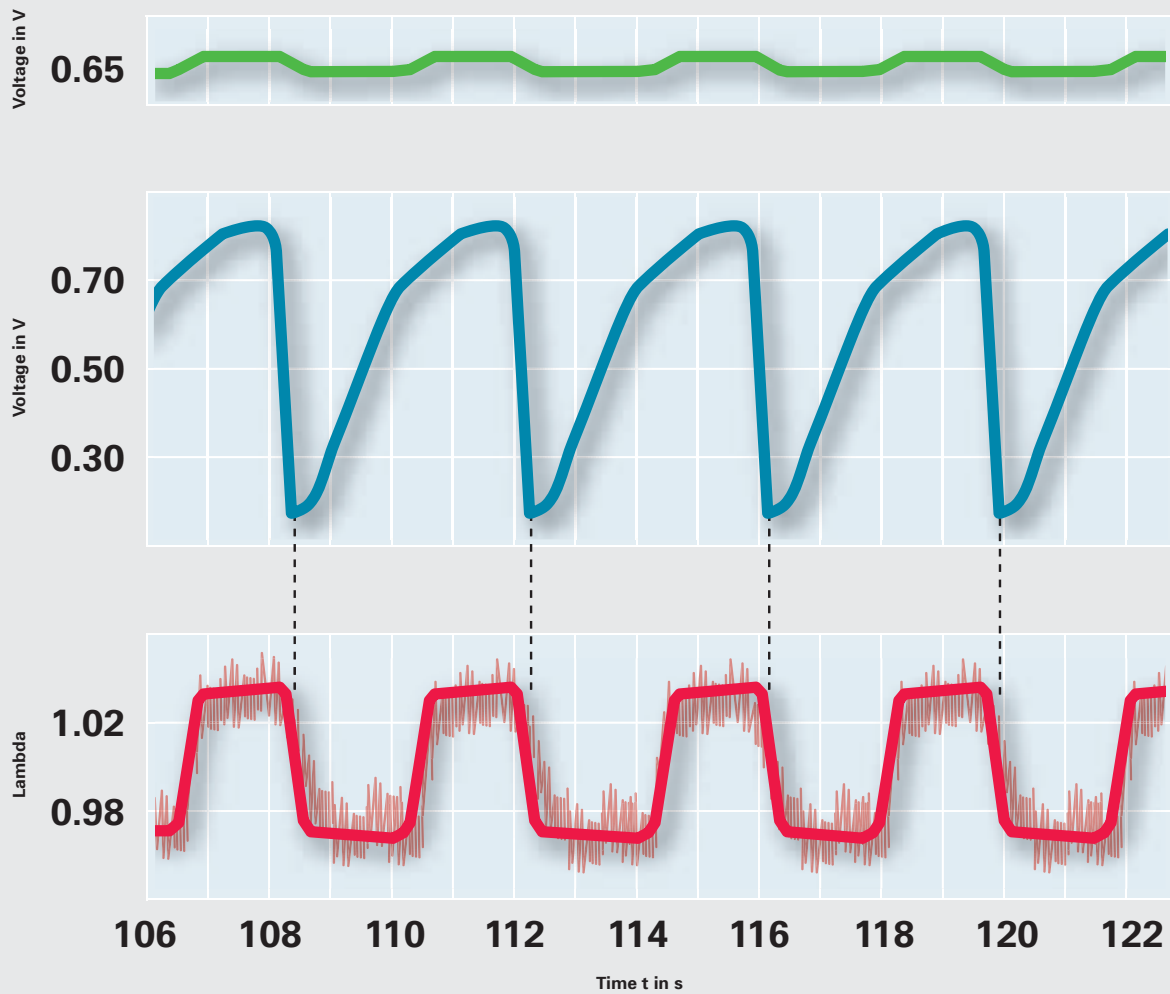
Reference



For basic information on exhaust emissions and engine management systems, please refer to Self-Study Programs 943003 Motor Vehicle Exhaust Emissions and 941003 Engine Management Systems.

SULEV 2.0L TFSI Engine

Signal Characteristics of the Oxygen Sensors



- Oxygen Sensor 3 Behind Three Way Catalytic Converter G287
- Oxygen Sensor Behind Three Way Catalytic Converter G130
- Heated Oxygen Sensor G39 (before primary catalytic converter)

Automatic Starter Control in the Audi A3

To ensure that the Audi A3 easily achieves SULEV exhaust emission limits, an automatic starter control system is used.

The ECM does not allow fuel to be injected into the combustion chamber until a pressure of at least 870 psi (60 bar) is measured in the fuel rail at start-up. This pressure is necessary to keep raw hydrocarbon emissions to an absolute minimum.

The complete starting cycle is performed automatically after briefly turning the ignition key to the start position.

Requirements for Starting

On vehicles with manual transmissions, the starter motor will only engage when the clutch pedal is fully depressed.

On vehicles with automatic transmission, the selector lever must be in position "P" or "N," in addition to a short press on the brake pedal.

Starting Sequence

(refer to diagram on next page)

To activate the starter motor, both signal lines (1) and (2) are pulled to ground by the ECM. One of the two lines is pulled to ground for approximately three seconds for diagnostic purposes. The other line is always diagnosed when the engine is started.

After completion of the power-off diagnostics, both lines are diagnosed continuously by means of pulses with a short duration of only a few milliseconds. This results in a mean voltage level of approximately 3 to 9 volts.

When line (1) is pulled to ground, battery voltage will again be present at the line (3), causing Power Supply Relay Terminal 50, J682 to close. Likewise for diagnostic purposes, the actual circuit status of the J682 load output is fed back across the diagnostic line (4) to the ECM and Vehicle Electrical System Control Module J519.

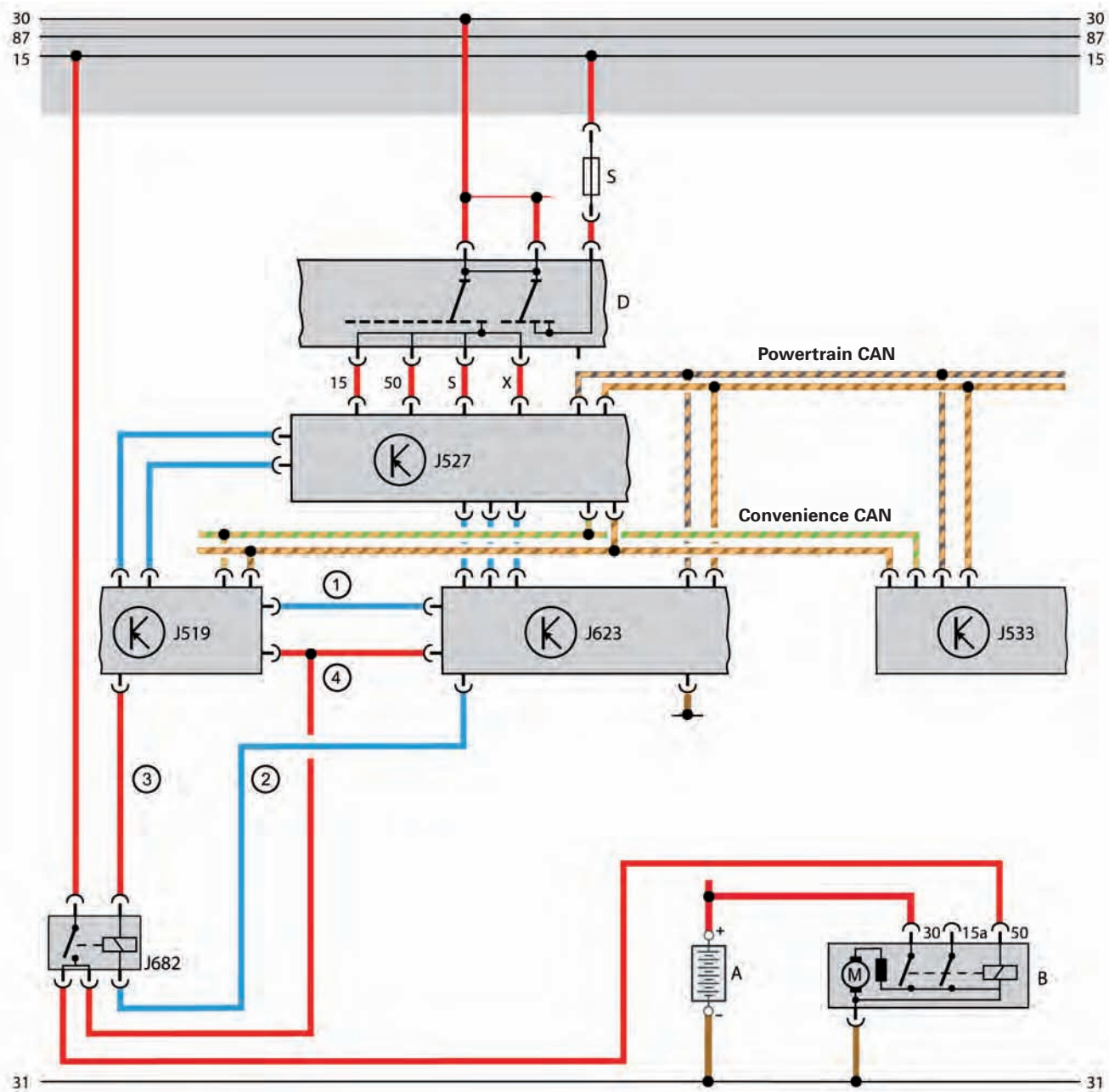
Because the starter motor has high inductance, it takes up to approximately three seconds after the opening of Power Supply Relay J682 until the ground signal is restored on the diagnostic line (4).

Effects of Failure

If a fault relevant to starting is entered in memory, only one manual start will be performed as a substitute response. The starter will only be activated as long as the ignition key is turned to the start position and held there.

SULEV 2.0L TFSI Engine

Function Diagram



Legend

A Battery

B Starter

D Ignition/Starter Switch

J519 Vehicle Electrical System Control Module

J527 Steering Column Electronic Systems Control Module

J533 Data Bus On Board Diagnostic Interface

S Fuse

① Start enable signal: is pulled to ground by the ECM when a start request is received

② Ground connected signal from ECM

③ Connected terminal 30

④ Diagnostic line

Operating Modes

After cold-starting the engine, various operating modes and fuel injection strategies are implemented:

- Stratified start (high-pressure fuel injection)
- Catalyst heating by homogeneous split dual injection, in conjunction with secondary air injection
- Dual injection during the engine warm-up phase



Stratified Start

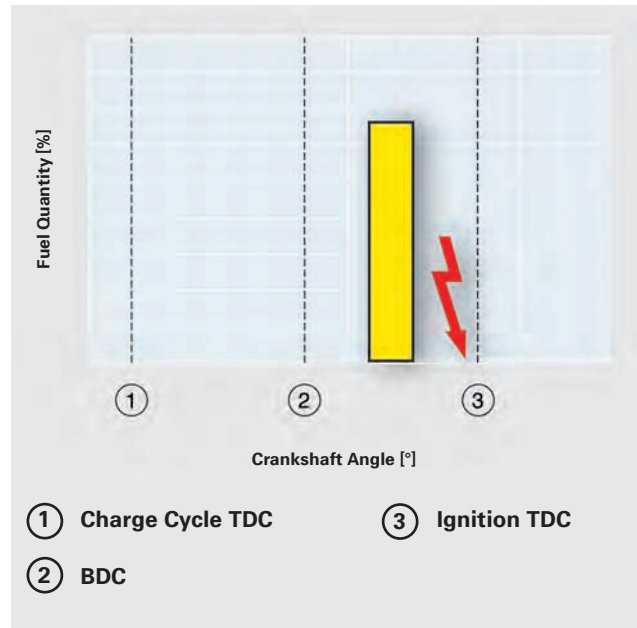
(high-pressure fuel injection)

When the rail pressure exceeds 60 bar (absolute) the injection enable signal is issued by the ECM. This occurs when the full starting fuel charge is injected during the compression phase until 60° crankshaft angle before ignition TDC.

At this stage in the process, both cylinder pressure and temperature are already considerably elevated, enabling the injected fuel to evaporate more efficiently.

Ingress of raw fuel into the combustion chamber is considerably reduced. The resulting, minimal fuel film on the cylinder walls is necessary to ensure extremely low raw hydrocarbon emissions at engine start-up.

A richer mixture forms in proximity to the spark plug, thereby creating more stable ignition conditions.



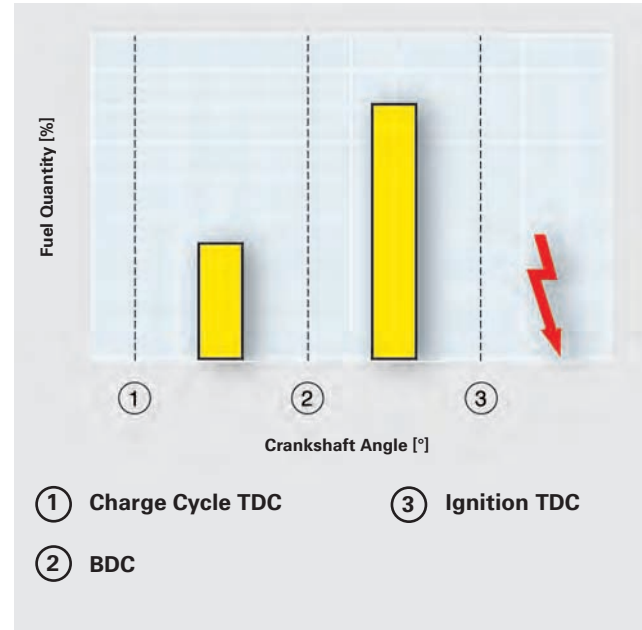
SULEV 2.0L TFSI Engine

Catalyst Heating with Dual Injection and Secondary Air Injection

To achieve good idling quality, a special characteristic map has been selected. In this map the following parameters relevant to exhaust emissions have been adapted:

- Fuel rail pressure
- Injection timing of first injection during the intake phase
- Injection timing of second injection during the compression phase
- Fuel split during first and second injections (approximately 70% during first injection)
- Intake camshaft adjustment
- Position of the intake manifold flaps (open/closed)
- Ignition angle adjustment towards retard (up to 21° after TDC)
- Combustion chamber air ratio

By using the secondary air system, exhaust gas temperature has been increased while reducing hydrocarbon emissions.



Dual Injection During the Engine Warm-Up Phase

The catalytic converter heat-up phase is followed by the engine warm-up phase, where one dual injection is performed per working cycle. The main part of the fuel charge (approximately 80%) is injected synchronous with the intake cycle, and the remainder (approximately 20%) during the compression phase.

During the engine warm-up phase, dual injection is performed within the mapped range at engine speeds of less than 3000 rpm. At the same time, the intake manifold flaps are closed to increase flow intensity.

The advantage of this operating mode is that considerably less fuel is deposited on the cylinder walls due to the low penetration depth of the fuel during second injection when the engine is still not fully warmed up.

Raw hydrocarbon emissions are lower, and entrainment of fuel into the engine oil is kept to a minimum.

Compliance with Statutory Limits (PremAir®)

When evaluating the environmental compatibility of vehicles, the EPA awards “credits” for technical measures designed to improve air quality. These credits can be used to offset fleet emissions that are over the limit.

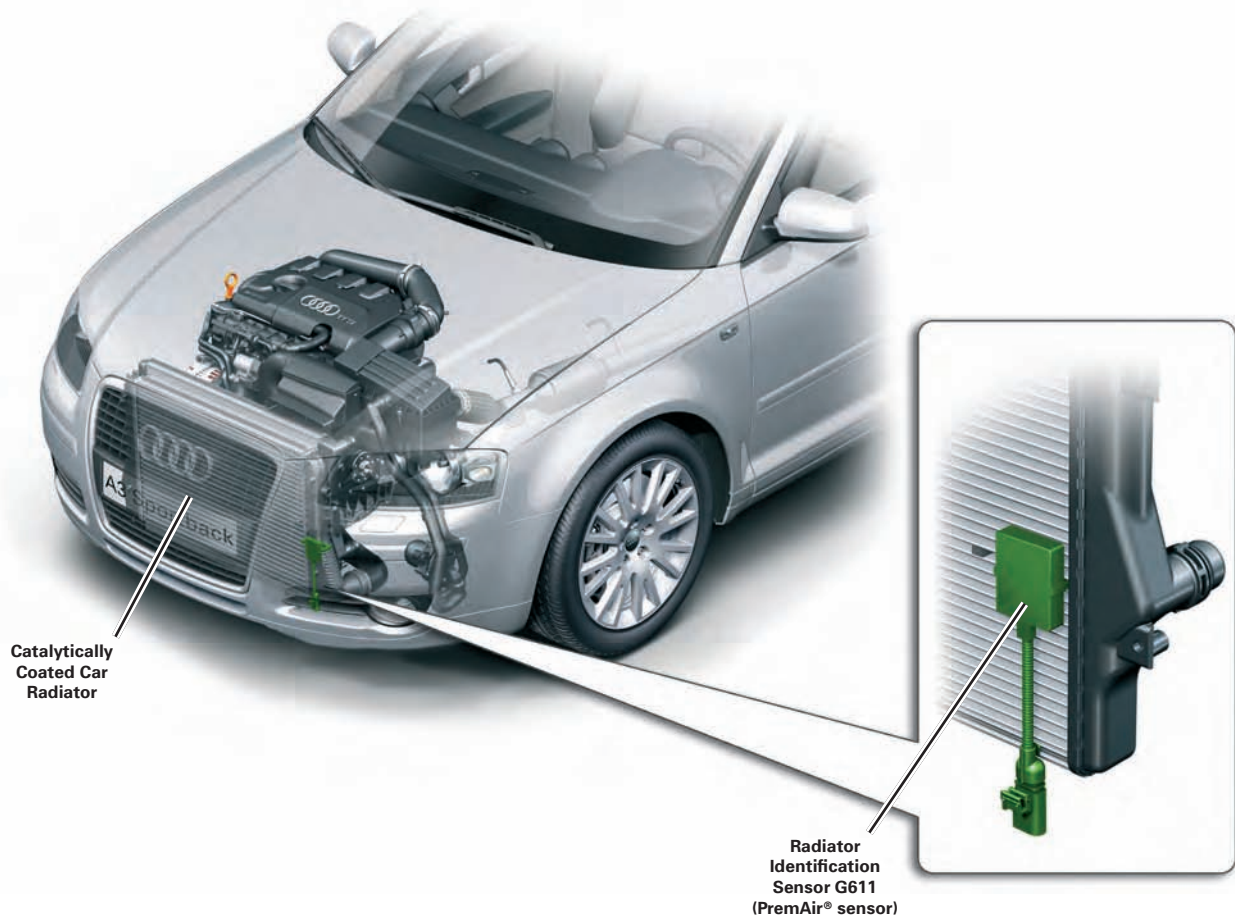
For this reason, a radiator with a special catalytic coating is used on the Audi A3.

This PremAir® technology* contributes to improving air quality. In exchange, the California Air Resources Board allows a higher NMOG* limit.

*NMOG

This abbreviation stands for “Non Methane Organic Gases” and encompasses all hydrocarbon emissions except methane.

Overview of the Components



SULEV 2.0L TFSI Engine

Function

The entire cooling surface of the car's radiator is coated with catalytic material.

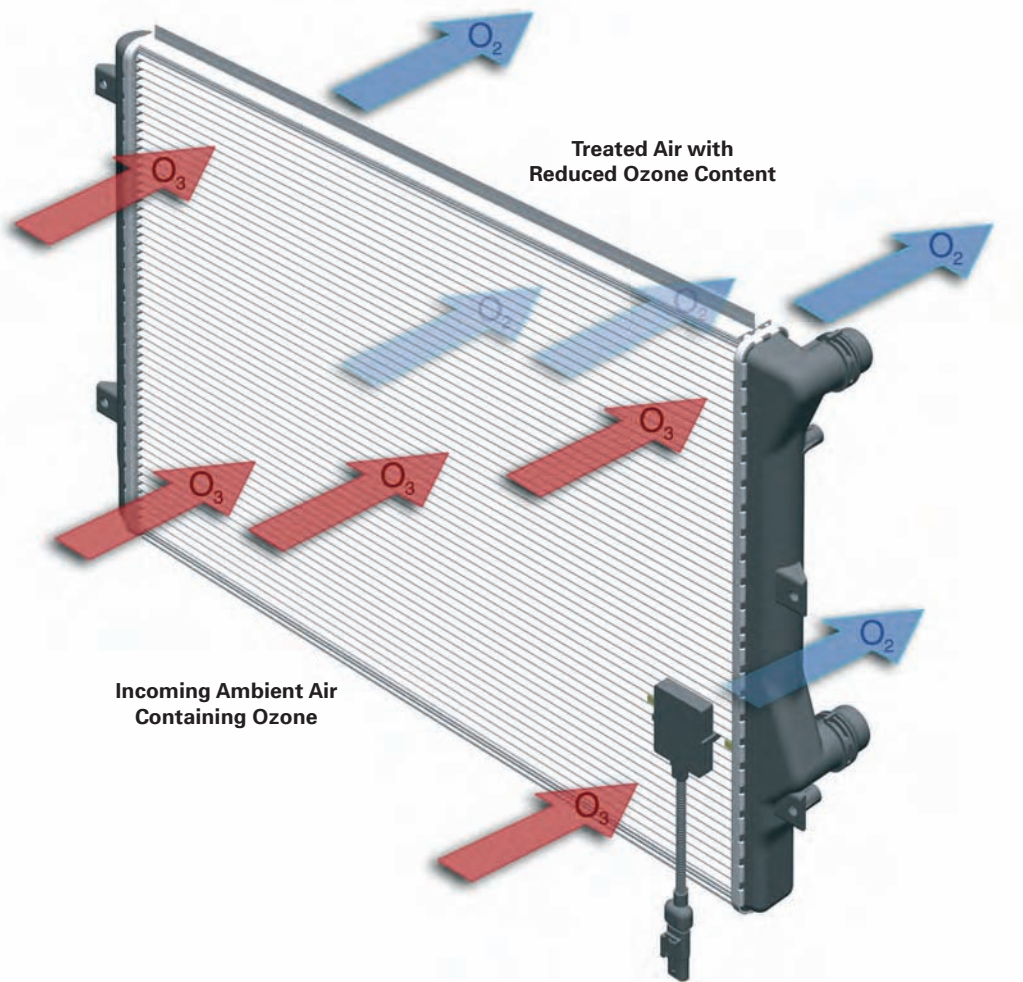
When air flows through this specially coated radiator, the ozone in the air is converted to oxygen (chemical symbol O_2). Ozone (chemical symbol O_3) is a gas which is harmful to health.

Given that the air in a car radiator can flow at up to two kilograms per second, a car with a PremAir® radiator makes a significant contribution to reducing near-surface ozone levels. The efficiency of this technology is particularly high in strong sunlight and at high air pollution levels.

This ozone catalyst technology is also used on aircraft, where it prevents stratospheric ozone from entering the cabin through the air conditioning system. The same technology is used in printers and copiers.

To receive EPA "credits" however, the Air Resources Board (ARB) requires not only a PremAir® radiator installed on the vehicle, but also a monitoring system that ensures its proper function and reliability at all times.

Therefore, this special radiator is monitored by Radiator Identification Sensor G611.



Radiator Identification Sensor G611

Requirements

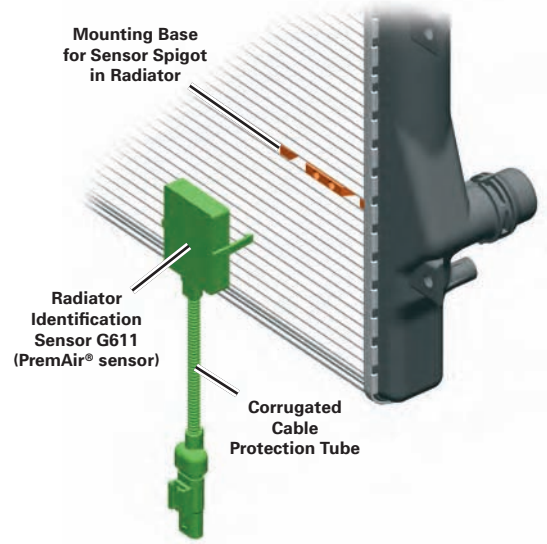
The purpose of Radiator Identification Sensor G611 is to prevent:

- PremAir® radiator from being removed and replaced with a non-PremAir® radiator
- G611 from being removed for the purpose of reproducing the electronics or software
- G611 from being extensively cut out of the radiator and installed “elsewhere”

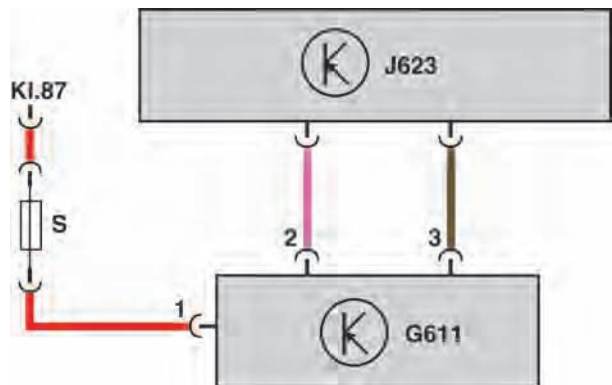
The requirements relating to Radiator Identification Sensor G611 are met as follows.

To check for the presence of the radiator, pre-determined distinguishing features (IDs) are stored in the ECM and in G611, and exchanged electronically.

Information is exchanged via LIN bus according to the master-slave principle. This means that Radiator Identification Sensor G611 is interrogated by the ECM. The IDs are transmitted in an encrypted form after the engine is started. If the codes no longer match (for example, due to tampering), a fault will be indicated.



Circuit Diagram



Integrated Temperature Sensor

A temperature sensor (NTC, Negative Temperature Coefficient) measures the temperature at the point of installation. This temperature is compared in the ECM with the temperature from Engine Coolant Temperature Sensor G62. The measured temperatures are transmitted to the ECM via LIN bus. In the ECM, the values are compared with a characteristic map and evaluated.

The temperature sensor is located in a specially shaped spigot on the sensor housing. During assembly, the sensor is bonded directly to a mounting base on the radiator.

The temperature sensor is made of cast polyurethane resin and is non-removable once attached. If, however, an attempt is made to remove the temperature sensor, the sensor spigot will break away from the housing causing it to become irreparably damaged, both electrically and mechanically.

This is a safeguard to ensure that all attempts at tampering will be detected. In the event of misuse, Malfunction Indicator Light K83 will be activated. In this case, both the radiator and Radiator Identification Sensor G611 must be replaced.

Legend

G611	Radiator Identification Sensor
J623	Engine Control Module (ECM)
Term 87	Main Relay, 12 Volt Power Supply
S	Fuse
—	Positive
—	Ground
—	LIN bus
1,2,3	Pins on Control Unit

SULEV 2.0L TFSI Engine

Temperature Sensor Diagnostics

The temperature sensor is diagnosed in Engine Control Module J623 only. To prevent tampering, no tests can be performed using the VAS Scan Tool.

Furthermore, the temperature signal is not transmitted as a voltage value, but as a LIN message. Before the ECM can diagnose the temperature sensor, several enabling conditions must be met. The values are then checked in multiple measurement windows.

Enabling Conditions of the Diagnostics

- Engine temperature greater than 207.5°F (97.5°C) (so thermostat is open)
- There is a 360-second time delay after the engine temperature exceeds 207.7°F (97.5°C) to ensure maximum flow through the radiator

Measurement Window is Active if:

- Engine has been idling for longer than 25 seconds
- Engine is then accelerated to part throttle or wide-open throttle within eight seconds – intake camshaft adjustment
- Measurement window is then active for 10 seconds in order to measure the temperature curves (gradients)

Three Measurement Windows are Required to Decide Whether the System is Operating Properly

Additional conditions for diagnosis:

- Diagnostics are disabled for 45 seconds at radiator fan ON/OFF or OFF/ON
- Ambient temperature greater than 48°F (9°C)

The temperature sensor cannot be tested by reading out a measured value. If the ECM detects a fault, the following fault memory entries are possible:

- P2568 implausible signal
- P2569 short circuit to ground
- P2570 short circuit to battery/open circuit
- U102E LIN message incorrect (implausible signal)
- U102F timeout (no communication)
- U1030 LIN bus inactive



Note

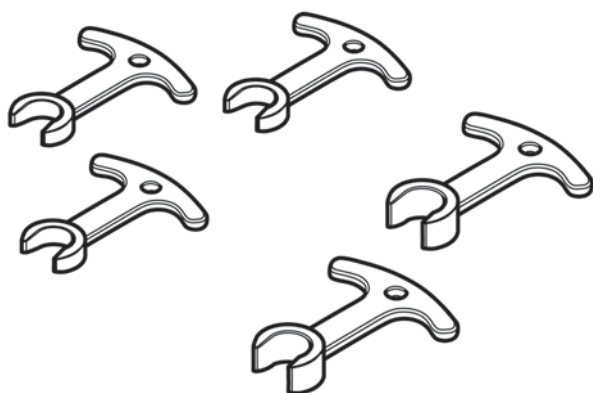


The diagnostic strategy described in this SSP will be replaced by a new strategy in the course of ongoing development from model year 2011 onward.

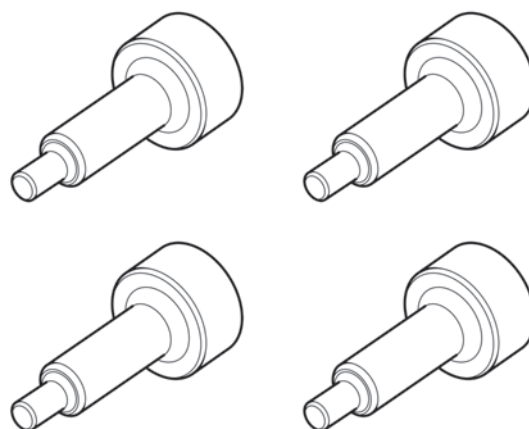
Special Tools



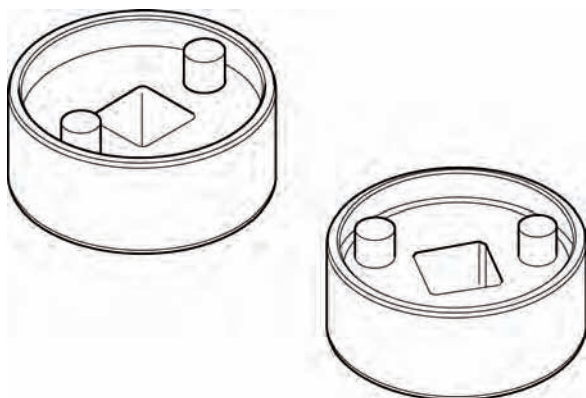
Here you can see the special tools for the 4-cylinder TFSI engines.



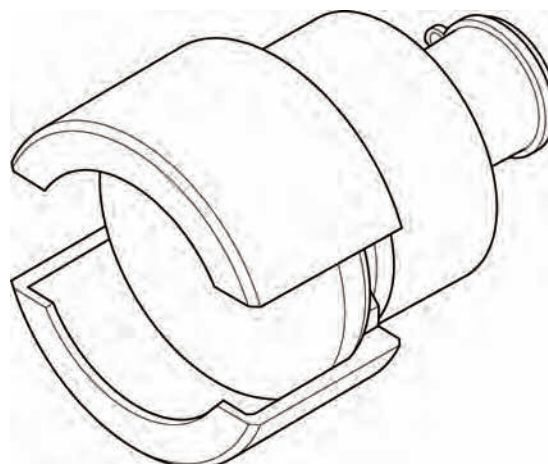
T40191/1 (narrow) and T40191/2 (wide) spacers for locating the AVS spline ends on the camshaft



T40196 adaptor for moving the AVS spline ends on the camshaft







T10352 assembly tool for removing and installing the inlet camshaft timing adjustment valve. The "/1" tool has offset stud bolts. It is used upwards of a defined engine version.



T10394 puller for removing the balancer shaft in conjunction with special tool T10133/3

EA 888 Engine Development

Overview of the Development Stages

Engine		Stage 0			
1.8L Longitudinal Engine					
1.8L Transverse Engine		EC: BYT	SOP: 01/2007	EOP: 06/2007	EU IV
		Initial Rollout of the EA888 Engine Series			
2.0L Longitudinal Engine					
2.0L Transverse Engine					

You will find explanatory notes on the abbreviations used in this table on page 48.

EA 888 Engine Development

Stage 1

Stage 2

EC: CABA	SOP: 02/2008	EOP: 09/2008	EU IV	EC: CDHA	SOP: 09/2008	EOP: – / –	EU V
EC: CABB	SOP: 07/2007	EOP: 05/2008	EU IV	EC: CDHB	SOP: 06/2008	EOP: – / –	EU V
EC: CABD	SOP: 10/2007	EOP: 11/2008	EU IV				
Modifications to Stage 0 (1.8L Transverse Engine): <ul style="list-style-type: none"> – Positive Crankcase Ventilation – Self-Regulating Oil Pump 				Modifications to Stage 1: <ul style="list-style-type: none"> – Main Bearing Diameter Reduced from 58 to 52 mm – Modified Piston – Modified Piston Rings – Different Honing Process – Ixetic Vacuum Pump 			

EC: BZB	SOP: 06/2007	EOP: 06/2008	EU IV	EC: CDAA	SOP: 05/2008	EOP: – / –	EU V
Modification to Stage 0: <ul style="list-style-type: none"> – Positive Crankcase Ventilation 				Modifications to Stage 1: <ul style="list-style-type: none"> – Diameter of Main Bearing Reduced from 58 to 52 mm – Modified Piston – Modified Piston Rings – Different Honing Process – Self-Regulating Oil Pump – Ixetic Vacuum Pump – Fuel Supply Line (routing) – Turbocharger Control Rod in Accordance with EA113 			

EC: CDNA	SOP: 22/2009	EOP: – / –	EU II – V
EC: CDNB	SOP: 06/2008	EOP: – / –	EU V
EC: CDNC	SOP: 06/2008	EOP: – / –	EU V
EC: CAEA	SOP: 01/2009	EOP: – / –	ULEV II
EC: CAEB	SOP: 08/2008	EOP: – / –	ULEV II
Modifications to Stage 1 (1.8L Longitudinal Engine): <ul style="list-style-type: none"> – Audi Valvelift System (AVS) – Modified Piston – Modified Piston Rings – Different Honing Process – Ixetic Vacuum Pump – Hitachi Generation III High-Pressure Fuel Pump – New Air Mass Meter 			

EC: CAWB	SOP: 11/2007	EOP: 05/2008	EU IV	EC: CCZA	SOP: 05/2008	EOP: – / –	EU V
EC: CBFA	SOP: 02/2008	EOP: 05/2009	PZEV, SULEV	EC: CCXA	SOP: 05/2009	EOP: – / –	BIN 5/ULEV II
EC: CCTA	SOP: 05/2009	EOP: 05/2009	BIN 5, ULEV II				
Modification to Stage 0 (1.8L Transverse Engine): <ul style="list-style-type: none"> – Positive Crankcase Ventilation 				Modifications to Stage 1: <ul style="list-style-type: none"> – Modified Piston – Modified Piston Rings – Different Honing Process – Self-Regulating Oil Pump – Ixetic Vacuum Pump – Hitachi Generation III High-Pressure Fuel Pump – Fuel Supply Line (routing) – New Air Mass Meter 			

EA 888 Engine Development

Technical Features

Technical Features of the 4-Cylinder TFSI Engines

Engine	1.8L TFSI	1.8L TFSI	1.8L TFSI
Engine Codes	CDHA, CABA	BYT, BZB	CDAA, CABB, CDHB
Displacement in cm ³	1789	1789	1789
Max. Power in kW @ rpm	88 @ 3650 – 6200	118 @ 5000 – 6200	118 at 4500 – 6200
Max. Torque in kW @ rpm	230 @ 1500 – 3650	250 @ 1500 – 4200	250 at 1500 – 4500
Bore in mm	82.5	82.5	82.5
Stroke in mm	84.1	84.1	84.1
Compression Ratio	9.6 : 1	9.6 : 1	9.6 : 1
Fuel in RON	95/91*	95/91*	95/91*
Injection/Ignition System	FSI	FSI	FSI
Firing Order	1–3–4–2	1–3–4–2	1–3–4–2
Knock Control	Yes	Yes	Yes
Charging	Yes	Yes	Yes
Exhaust Gas Recirculation	No	No	No
Intake Manifold Change-Over	No	No	No
Variable Valve Timing	Yes	Yes	Yes
Secondary Air System	No	No	No
Audi Valve Lift System (AVS)	No	No	No
Self-Regulating Oil Pump	Yes	No	Yes
Intake Manifold Flaps	Yes	Yes	Yes

*Unleaded RON 91 petrol may also be used with a slight reduction in engine power

**The engine develops 130 kW, but all other parameters are identical

Abbreviations used in the table:

EC Engine Code

SOP Start of Production

EOP End of Production

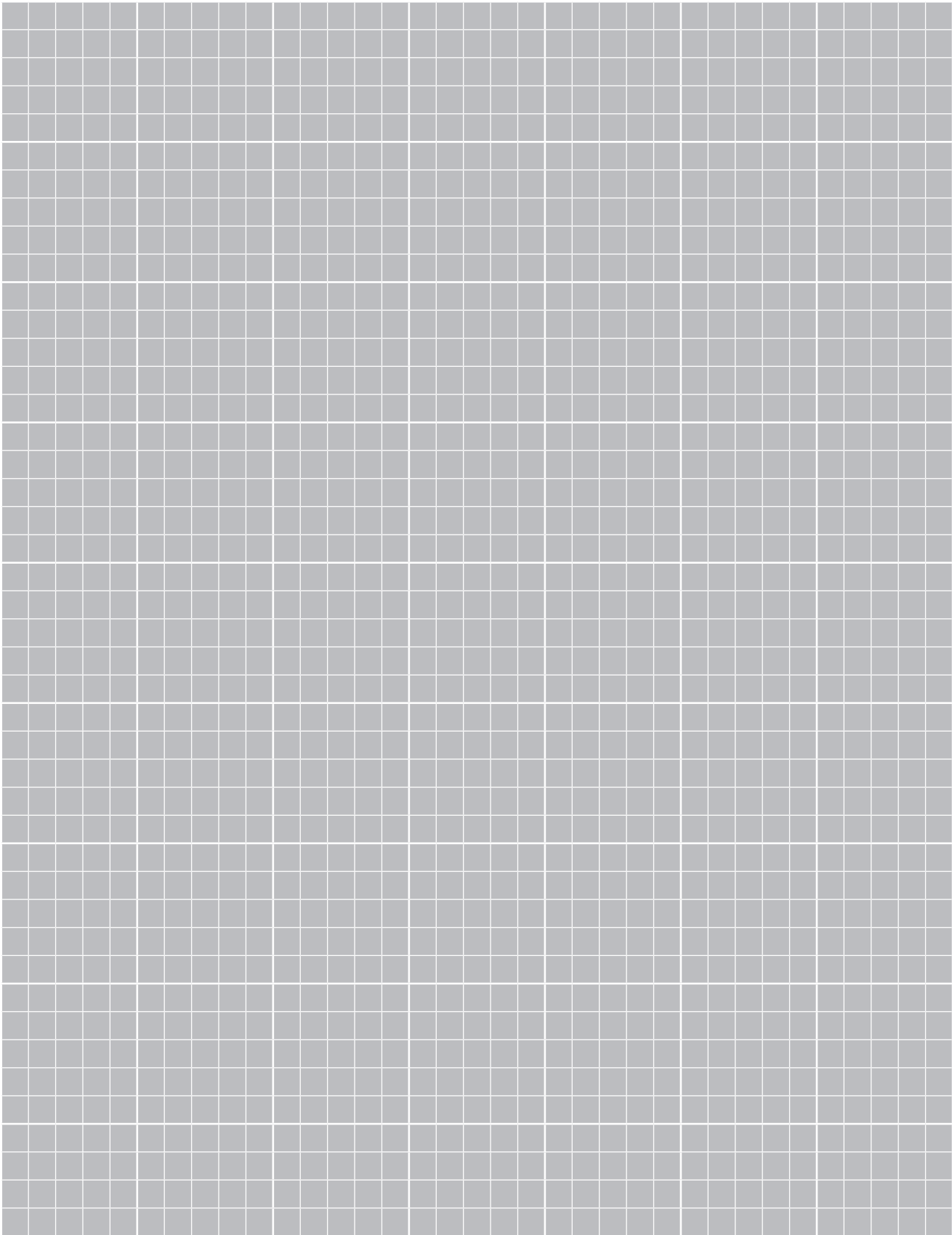
EA113 Engine series 1.8l MPI

Exhaust emission standards:

EU IV, EU V, BIN 5, PZEV, SULEV, ULEV II

EA 888 Engine Development

1.8L TFSI	2.0L TFSI	2.0L TFSI	2.0L TFSI	2.0L TFSI
CABD	CAEA, CDNB, (CDNA)**	CAWB, CBFA	CCTA, CCZA	CAEB, CDNC
1789	1984	1984	1984	1984
125 @ 4800 – 6200	132 @ 4000 – 6000	147 @ 5100 – 6000	147 @ 5100 – 6000	155 @ 4300 – 6000
250 @ 1500 – 4800	320 @ 1500 – 3900	280 @ 1700 – 5000	280 @ 1700 – 5000	350 @ 1500 – 4200
82.5	82.5	82.5	82.5	82.5
84.1	92.8	92.8	92.8	92.8
9.6 : 1	9.6 : 1	9.6 : 1	9.6 : 1	9.6 : 1
95/91*	minimum 95	95/91*	95/91*	minimum 95
FSI	FSI	FSI	FSI	FSI
1–3–4–2	1–3–4–2	1–3–4–2	1–3–4–2	1–3–4–2
Yes	Yes	Yes	Yes	Yes
Yes	Yes	Yes	Yes	Yes
No	No	No	No	no
No	No	No	No	no
Yes	Yes	Yes	Yes	Yes
No	No	Yes (CBFA only)	No	no
No	Yes	No	No	Yes
Yes	Yes	No	Yes (CCZA only)	Yes
Yes	Yes	Yes	Yes	Yes



Knowledge Assessment

An on-line Knowledge Assessment (exam) is available for this Self-Study Program.

The Knowledge Assessment may or may not be required for Certification.

You can find this Knowledge Assessment at:

www.accessaudi.com

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- Click on the “ACADEMY” tab
- Click on the “Academy Site” link
- Click on the “CRC/Certification” link
- Click on Course Catalog and select “922903 — Audi 2.0L 4-Valve TFSI Engine with AVS”

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Certification Resource Center (CRC)
1-877-283-4562
(8:00 a.m. to 8:00 p.m. EST)

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audicrhelpdesk@touchstone-group.com